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WATER POLLUTION INVESTIGATION: CALUMET AREA OF LAKE MICHIGAN. VOLUME II (APPENDICES)

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16. Abstracts An investigation of the Calumet area of Lake Michigan was conducted. The objective was to determine trends in water quality, to determine effluent loads entering the Lake, and to predict reductions in effluents needed to achieve Lake water quality standards. The report describes the status of industrial and municipal effluent sources. Effluent data were compiled from NPDES permit applications and operating reports. These were checked by a field sampling program.

Water quality data were compiled from several sources. We also conducted field measurements in the Indiana Harbor Canal (IHC) and at 16 Lake stations. We located the plume from the IHC by aerial observation and by measurements using existing pollutants as tracers. Current meters installed in the Lake for one month allowed us to describe the mechanisms that appear to govern dispersion of the IHC plume. The report contains chapters assessing the impact of each of the more important pollutants, and gives recommendations for reduction of some effluent loads. Appendices are included on the biological impact of pollutants on the Calumet area of Lake Michigan.

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This report has been developed under auspices of the Great Lakes Initiative Contract Program. The purpose of the Program is to obtain additional data regarding the present nature and trends in water quality, aquatic life, and waste loadings in areas of the Great Lakes with the worst water pollution problems. The data thus obtained is being used to assist in the development of waste discharge permits under provisions of the Federal Water Pollution Control Act Amendments of 1972 and in meeting commitments under the Great Lakes Water Quality Agreement between the U.S. and Canada for accelerated effort to abate and control water pollution in the Great Lakes.

This report has been reviewed by the Enforcement Division, Region V, Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

WATER POLLUTION INVESTIGATION: CALUMET AREA OF LAKE MICHIGAN

VOLUME 2

by

Richard H. Snow

IIT RESEARCH INSTITUTE

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Region V

Great Lakes Initiative Contract Program
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October 1974

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APPENDIX A

A REVIEW OF SELECTED RESEARCH ON THE BIOLOGY AND SEDIMENTS OF SOUTHERN LAKE MICHIGAN WITH PARTICULAR REFERENCE TO THE CALUMET AREA

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INTRODUCTION

Effluents of municipalities and industries can have pronounced ecological effects upon receiving waters. They may, because of some toxic components, eliminate many or most forms of life. Large amounts of oxygen-demanding organic matter may upset the oxygen regime, thus greatly modifying the biological community. Even non-toxic inorganic components can be biologically important by serving as plant nutrients, thus accelerating the process of eutrophication.

The resulting biological changes may be of great importance because of their economic impact. Excessive growths of algae and aquatic plants may increase the cost of municipal and industrial water treatment, and may interfere with usual recreational uses of water. Fish stocks usually change in composition to less desirable, and economically less valuable, species under the influence of pollution and eutrophication.

Because the biota of lakes and rivers changes gradually with increasing pollution and eutrophication, it is possible to assess the quality of the aquatic environment through a study of the biota. Much publicity is currently being given to constant monitoring apparatus for chemical parameters. Biologists have made use of a natural constant-monitoring system for many years, viz; the community of plants and animals living in the water.

This report is a review of literature on some components of the biota of Lake Michigan. It is, admittedly, a rather uneven treatment, giving greatest attention to the invertebrate bottom fauna. This is a reflection of the particular interests and experience of the author. Studies of the zooplankton are omitted entirely from this review, being the subject of a similar report by Gannon (1973).

The following pages place particular emphasis on knowledge of the south-western corner of the lake. The author has attempted to point out changes in the biota which may be related to pollution and/or eutrophication, especially that related to pollutants originating in the Calumet area.

BACTERIA

The natural bacterial flora of lakes remains relatively little studied and information on the bacteria of Lake Michigan, other than those of sewage origin, is limited.

Scarce (1965) and the Federal Water Pollution Control Administration (FWPCA 1968b) reported results of a study of 4100 samples from city harbors and 1200 samples from inshore area (within 10 miles of shore). Three families were most common, Achromobacteriaceae, Pseudomonaceae, and Eubacteriaceae. The Achromobacteriaceae were most prevalent, accounting for 95 to 99 per cent of the colonies examined from plates incubated at 20 and 35°C. Each family was represented by several genera. It is questionable to what extent the study presents a true picture of the lake's normal bacterial flora. Methods involving culturing are selective for those species well adapted to grow on the media used and under the oxygen and temperature conditions established during incubation (Scarce 1965, Robohm and Graikowski 1966). It has also become obvious that culture methods grossly underestimate density as established by direct counts (Bell and Dutka 1972).

Considerable more effort has been devoted to studies of abundance and distribution of bacteria of sewage origin. For the most part these investigations have been concerned with "coliform bacteria", believed largely to be represented by Escherichia coli, a species which is not normally pathogenic itself but which is indicative of recent fecal contamination of the water and, therefore, of the possible presence of pathogens.

Damann (1960) reported upon counts of coliform bacteria from a

Chicago water intake during the period 1926-1958. Methods used for estimating numbers apparently remained unchanged over this period. Highest annual average numbers were reported in 1940, 1941 and 1942 (Most Probable Number (MPN) 180, 222, and 250 per 100 milliliters, respectively). Damann saw fit to remark that it was during this period that, due to the demands of World War II, industry in the region was undergoing great expansion. Lowest annual average numbers occurred in 1950, 1952, and 1954 (MPN; 7, 7, and 8 per 100 ml). There was an apparent trend of decreasing coliform numbers, with an annual average MPN for 1926-1942 of 70 per 100 milliliters but for the period 1943-1958 of only 23 per 100 milliliters. The trend proved not significant at the 0.01% level, however (Fig. A-1).

Scarce (1965) discussed results of coliform counts on samples from 313 stations in the southern basin of Lake Michigan. Samples from offshore stations had little or (usually) no coliform content. Highest coliform densities occurred with greatest frequency near centers of urbanization along the western shore. For example, surface samples from 10 nearshore stations between the northern limit of Chicago and the eastern end of Gary, Indiana contained the following coliform densities:

estimated coliform density (cells/100 ml)	number of stations in range
<1	1
1-10	2
11-100	2
110-1000	4
1100-2000	1
	$\Sigma = 10$

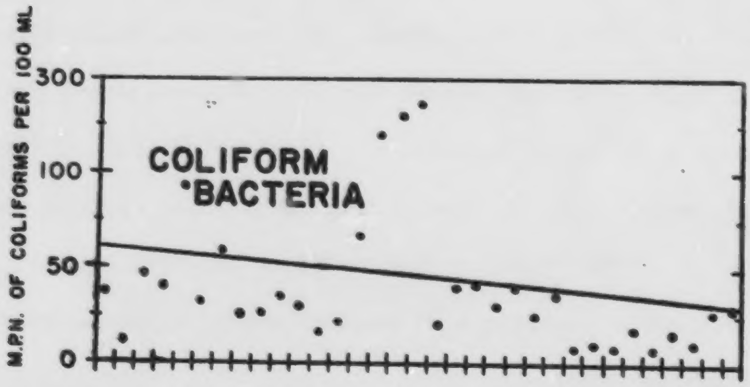


Figure A-1. Regression of Most Probable Number (MPN) of coliform bacteria against year for collections at Chicago, 1926-1958. The trend of decreasing numbers did not prove statistically significant at the 0.01% level. (From Damann 1960)

The average density here would obviously be much higher than what one would expect from the data presented by Damann (1960) and the discrepancy may reflect differences in methodology. Other recent reports indicate that high coliform bacteria concentrations occur frequently at several water intakes and most beaches along southwestern Lake Michigan (Holleyman 1960, FWPCA 1968b). For example, Rainbow Beach and Calumet Park Beaches failed to meet the joint federal-state criteria for bacterial levels approximately 66% of the time during 1966, 20% of the time during 1967, and 33% of the time during 1968. Some beaches had even worse records (FWPCA 1968c). High coliform bacteria counts in this area occur mostly under conditions of onshore winds following heavy precipitation (Holleyman 1968).

Scarce and Peterson (1966) investigated the coliform abundance and the incidence of selected pathogenic bacteria in several streams of the Chicago and Calumet area. The waters studied are regularly or occasionally tributary to Lake Michigan. Results reflected gross pollution of sewage origin. Total coliform geometric mean densities ranged to almost 700,000 per 100 ml in the Sanitary and Ship Canal. Individual determinations ran as high as 25,000,000 per 100 ml in this waterway. A station on the Grand Calumet River had a geometric mean coliform density of 3,000,000 per 100 ml and fecal streptococcus concentrations as high as 260,000 per 100 ml. Salmonellae were present throughout the stream systems investigated. These included 23 strains, all pathogenic. Pathogenic enteroviruses were found in 27 per cent of the stream samples. It is easy to understand why intolerable bacterial densities in the lake follow heavy rains which accelerate flushing of these water courses.

High numbers of coliforms and pathogens of fecal origin would not persist for long in the lake if it were not for continuing inputs. Hedrick, Meyer and Kossoy (1962) studied the survival of *E. coli*, *Salmonella typhosa*, *S. paratyphi*, *S. schottmuelleri*, *Shigella dysenteriae*, *S. paradysenteriae*, and *S. sonnei* using pure cultures and sterile-filtered Lake Michigan water obtained at the South District Filtration Plant in Chicago. All but the first of these are enteric parasites and pathogens. With few exceptions, they found substantial mortality of these bacteria within 24 hr. They attributed this to a toxic factor in the lake water since corresponding studies employing well water resulted in smaller decreases or increases in bacterial numbers. With the possible exception of *Salmonella schottmuelleri*, the enteric pathogens were more sensitive to the toxic factors in Lake Michigan water than was *E. coli*. In general, the *Shigella* strains, *Salmonella typhosa* and *S. paratyphi* usually underwent at least a 50% reduction of numbers within 24 hr, while *S. schottmuelleri* and *E. coli* either grew or suffered less than a 50% loss in 24 hr.

At the same time, Hedrick, Meyer and Kossoy (1962) also studied the survival of coliform bacteria present in untreated water from the South District Plant. During the period July 1952 - Sept. 1953 they found great reduction in numbers of coliforms during 24 hr. However, in the winter and early spring of 1954 there was very little loss of coliforms during their 24 hr experiments. Comparison of their data with that of earlier studies (Noble and Gullans 1955) showed that the short survival times are the usual case in Lake Michigan.

Results from winter and spring of 1954 are unusual but remain unexplained.

Survival of E. coli and S. schottmuelleri in the first-mentioned series of experiments paralleled very closely the behavior of the coliforms in the tests with untreated lake water. Thus it seems that the "toxic factor" in Lake Michigan water is at times less effective at reducing numbers of coliforms and S. schottmuelleri but even on these rare occasions, numbers of many important pathogens are quickly reduced.

ALGAE

Phytoplankton Abundance

The FWPCA (1968a) reported that in 1962-63 deep-water (open lake) areas supported low abundance of phytoplankton, generally in the range 100-300 organisms/ml. Nutrient rich inshore areas, on the other hand, generally had abundances exceeding 500/ml. (Fig. A-2,3,4). Phytoplankton were very abundant in the Chicago-Calumet area with densities reaching 1298/ml in 1962 and 2,143 in 1963.

Beeton (1969) reported that open lake plankton abundance has generally been about 1/3 that at the Chicago intake.

It is obvious from Figures A-2,3 and 4 that the southwestern corner of the lake was, in 1962-63, unique in having high phytoplankton densities in both spring and fall. Other inshore areas on the western side of the southern basin had peak densities in fall while along the eastern and northwestern shores the peak came in spring.

This may represent a regular difference in the annual cycle of abundance in these areas. Damann (1966) pointed out that over a period of many years phytoplankton sampled at Chicago has had two peaks of abundance annually while abundance was unimodal at Milwaukee and in the open lake. It is difficult to know what importance to ascribe to this observation, other than that the Chicago area seems a unique area in Lake Michigan. More recently, Holland (1969) has observed a bimodality in diatom abundance in Green Bay, the most eutrophic area of Lake Michigan. Beeton (1969) feels that a bimodal cycle of phytoplankton abundance may be characteristic of more productive areas in the Great Lakes.

Data from the Chicago water intake show that phytoplankton abundance

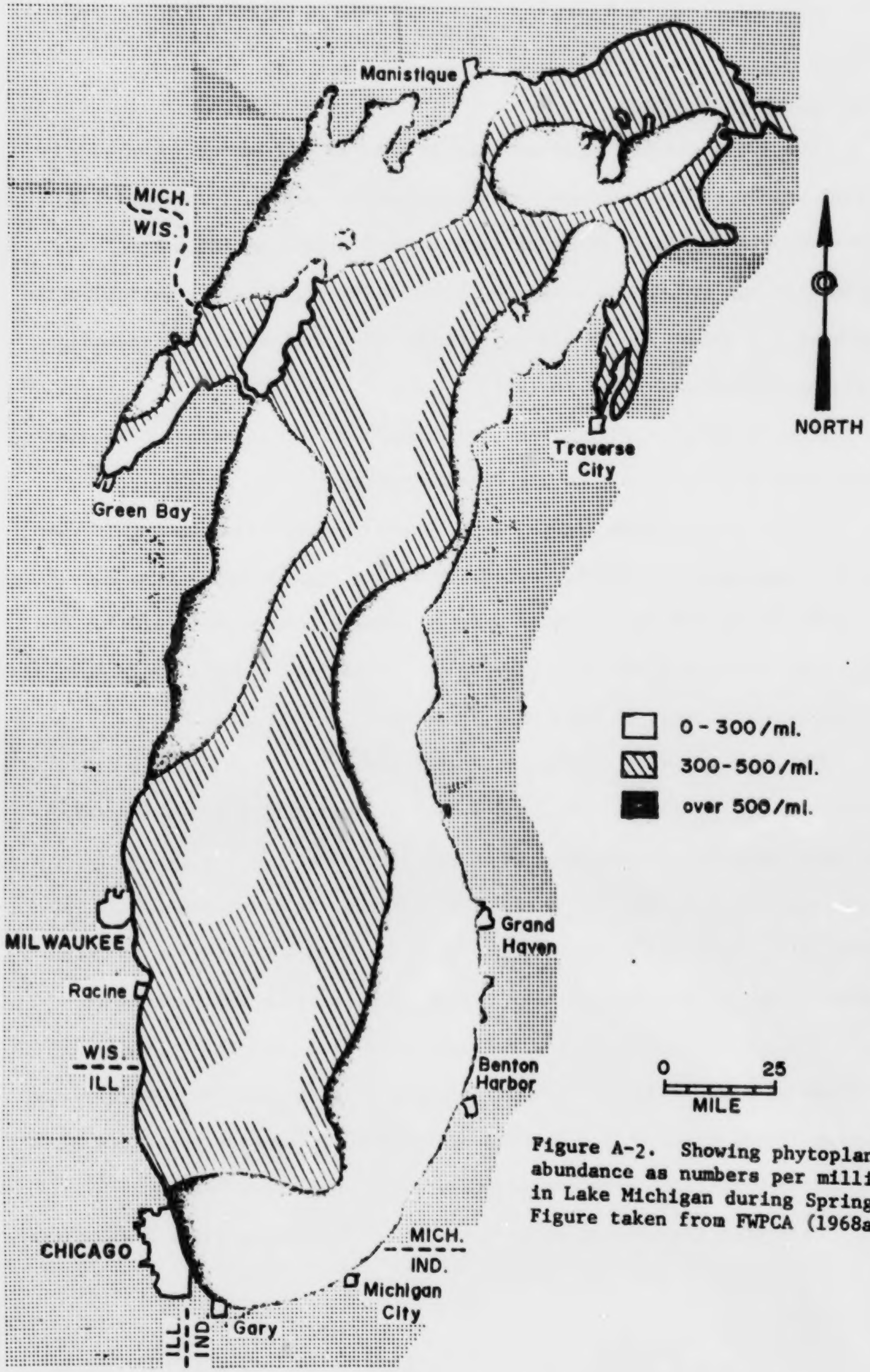

Manistique
MICH.
WIS.
NORTH
Traverse City
Green Bay
0 - 300/ml.
300-500/ml.
over 500/ml.
Grand Haven
MILWAUKEE
Racine
WIS.
ILL.
Benton Harbor
0
25
MILE
CHICAGO
MICH.
IND.
Michigan City
ILL.
IND
Gary

Figure A-2. Showing phytoplankton abundance as numbers per milliliter in Lake Michigan during Spring 1962. Figure taken from FWPCA (1968a).

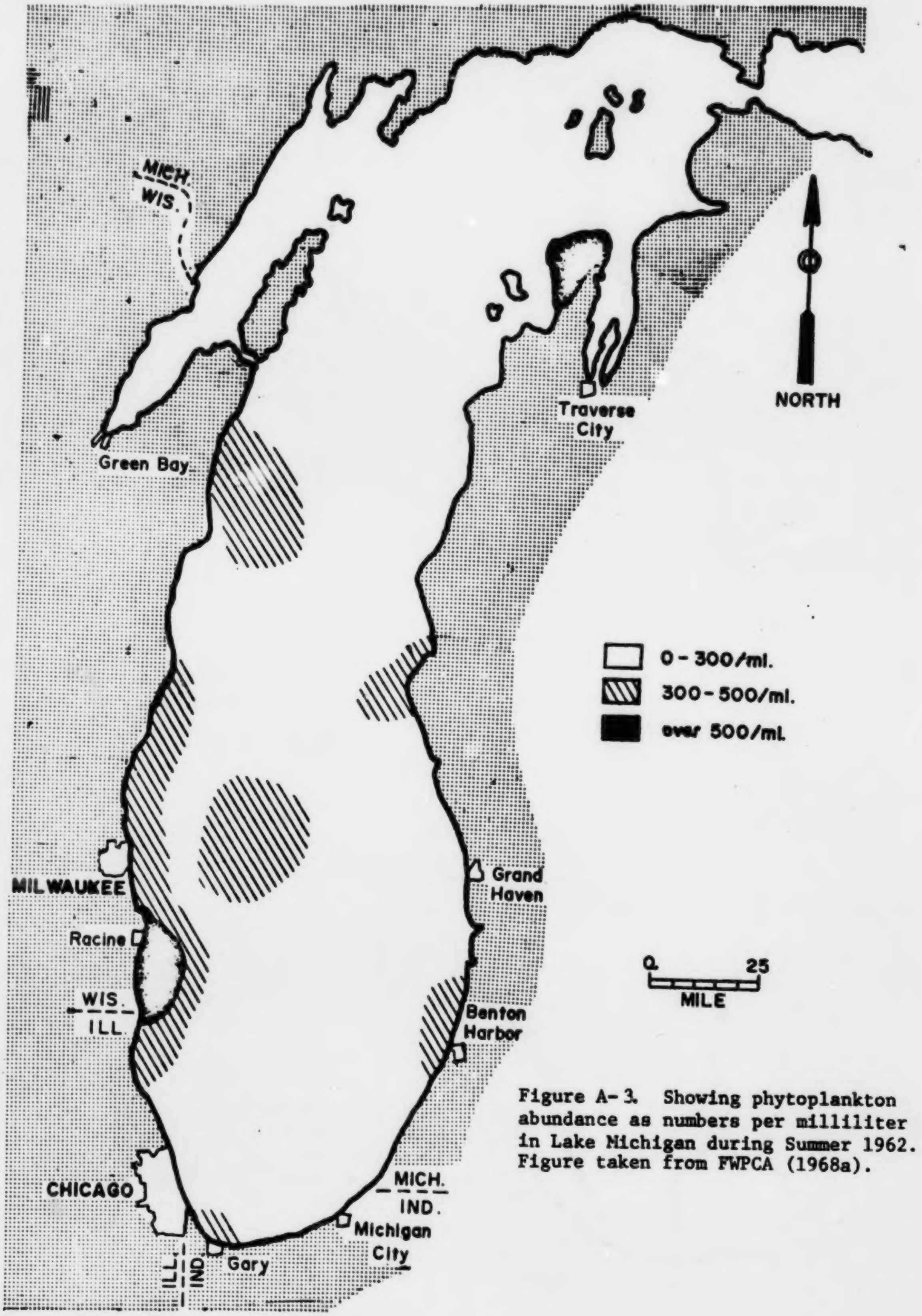

MICH.
WIS.
Green Bay
Traverse City
NORTH
0 - 300/ml.
300 - 500/ml.
over 500/ml.
MILWAUKEE
Racine
WIS.
ILL.
Grand Haven
Benton Harbor
0
25
MILE
CHICAGO
MICH.
IND.
Michigan City
ILL.
IND.
Gary

Figure A-3. Showing phytoplankton abundance as numbers per milliliter in Lake Michigan during Summer 1962. Figure taken from FWPCA (1968a).

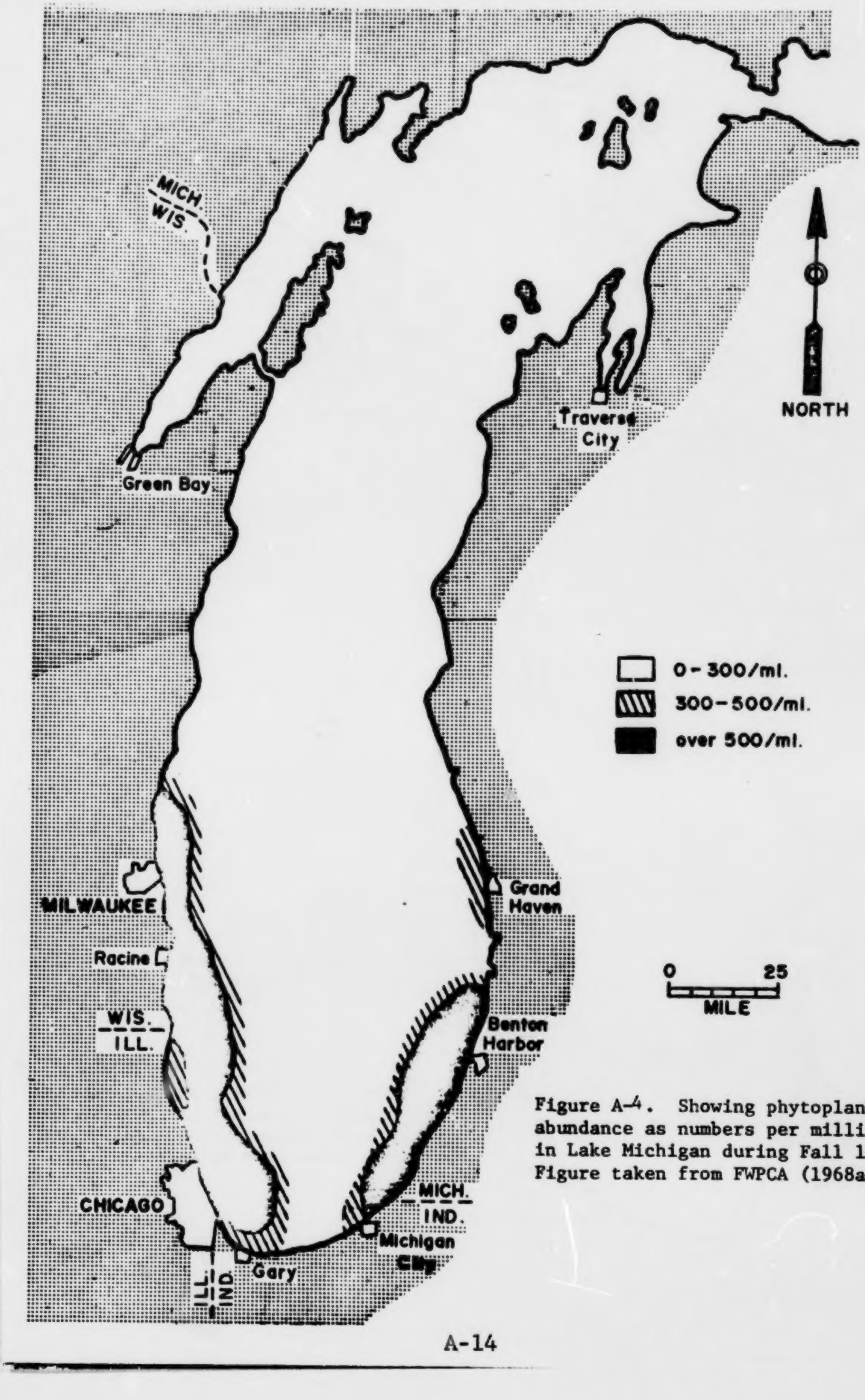

MICH
WIS.
Green Bay
Traverse City
NORTH
☐ 0-300/ml.
▨ 300-500/ml.
■ over 500/ml.
MILWAUKEE
Grand Haven
Racine
0
25
MILE
WIS.
ILL.
Benton Harbor
CHICAGO
MICH.
IND.
Michigan City
Gary
ILL.
IND.

Figure A-4. Showing phytoplankton abundance as numbers per milliliter in Lake Michigan during Fall 1962. Figure taken from FWPCA (1968a).

increased at an average of 13 organisms/ml per year during the period 1926 to 1958 (Fig. A-5, Damann 1960).

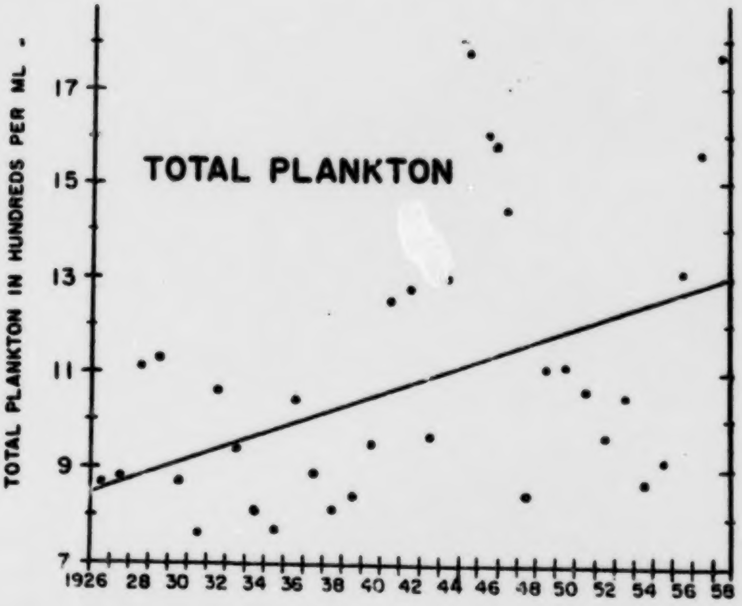


Figure A-5. Regression of annual standing crop of total plankton on collection year, in Lake Michigan at Chicago, 1926 through 1968. The trend with time was significant (b = 13.06 ± 4.6, t = 2.81, p < .01). (After Damann 1960.)

Composition of the Plankton Flora

In reviewing studies of the Lake Michigan phytoplankton, Davis (1966) drew attention to the nearly unanimous agreement of investigators that diatoms dominate the flora. For example, he cites Damann (1945) who reported that diatoms constituted an average of 94% of the phytoplankters over the course of the year of his study and at no time accounted for less than 89% of the total.

The dominant diatoms of open Lake Michigan are *Fragilaria crotonensis*, *Melosira islandica*, *Tabellaria flocculosa*, *Asterionella formosa*, *Cyclotella stelligera* and *C. michiganiana* (Holland 1969). This is very clearly an oligotrophic flora (Rawson 1956, Beeton 1965).

To some extent the extreme dominance of diatoms may represent an artifact of the methods used by most of those who have studied the Lake Michigan phytoplankton. Recent work done with special attention to other elements of the flora indicates that diatoms are frequently not dominant, at least in some inshore waters (Claflin and Beeton 1972). Algae other than diatoms which Davis (1966) reported to be abundant at times include; *Dinobryon*, *Ceratium*, *Anacystis*, *Chrooccus* and *Oocystis*.

It is becoming clear from recent studies that the flora of inshore waters may differ greatly from that in the main body of the lake (Holland and Beeton, 1972). Stoermer (1968) reported on pronounced inshore (less than 4 mi from shore)-offshore differences. He attributed these to a horizontal thermal discontinuity ("thermal bar") which was present during his two day study. Holland (1968, 1969) found several species of diatoms (*Diatoma tenue* v. *elongatum*, *Fragilaria crotonensis*, *Melosira ambigua*, *Stephanodiscus tenuis*, *Tabellaria flocculosa*) more abundant inshore than offshore during the period April - November 1965. Furthermore, generation times were less inshore than offshore. Obviously, these inshore-offshore differences are not exclusively short-term phenomena associated with thermal bars. The differences in distribution, abundance, and generation times of diatoms were related to inshore-offshore differences in nutrients. More recent studies (Beeton 1970) continue to illuminate great differences. These inshore-offshore differences are being emphasized because much of our knowledge of Lake Michigan plankton has resulted from studies of samples taken from municipal water intakes which are invariably located within a mile or two from shore. It is important to realize that results of such studies may not be validly extrapolated to the lake as a whole. The results are nevertheless important, for it is the inshore waters which serve most of our esthetic and recreational needs, from which we draw water, and where much commercial fishing is done. In terms of our interest in the Calumet area, knowledge of these pronounced inshore-offshore differences indicates that the only studies having direct relevance will be those done within a few miles of shore in the southern end of the lake.

Stoermer and Yang (1970) examined over 900 Lake Michigan phytoplankton samples collected between 1876 and 1967. They give a detailed account of the distribution and relative abundance of the dominant planktonic diatoms of the lake and have documented floristic changes during this 90 year period. They found that those diatoms which are favored by eutrophic conditions have increased in relative abundance in recent years. Changes in the diatom flora of the lake appeared first in nearshore waters and virtually all nearshore waters now have a flora radically different from that indicated by the earliest samples. Collections from the Chicago area in 1876-1881 contained most of the species which now are found exclusively in the open lake, although some of the species which are now characteristic of inshore waters were also present. This pattern, of new introductions to the flora appearing first in nearshore waters and later spreading to the open lake, was taken by Stoermer and Yang (1970) as evidence that the changes are caused by nutrient pollution and not natural phenomena. They predicted further changes in the flora, with perennial and oligotrophic species being replaced by seasonal species more favored by mesotrophic or eutrophic conditions. It was estimated that within 10-20 years changes may have progressed to the point where offshore diatom blooms would be considered esthetically objectionable. The authors did point out, however, that this was a very tenuous estimate because of the possibility that changing chemical conditions will result in a flora dominated by algae other than diatoms.

Recent experimental work by Schelske and Stoermer (1971, 1972) provides evidence that silica is sometimes limiting the growth of diatoms in Lake Michigan. Phosphorus, presumably the usual limiting nutrient at most times in the past, has been added to the lake in such quantities that it has allowed diatoms to grow up to the level of available silica. Relative to the needs of diatoms, phosphorus enters the lake in much greater quantities than does silica. The ratios indicate that 10 to 20 times more phosphorus is being added to the lake than can be utilized with present inputs of silica (Schelske and Callender 1970, Schelske and Stoermer 1972). Thus it can be expected that the composition of the planktonic flora will shift from near complete dominance of diatoms to a greater proportion of the less desirable nonsiliceous green and blue-green algae. Evidence indicates that this is happening (Schelske and Stoermer 1972).

Major changes can be expected to occur first in the southwestern section of the lake. During the summer of 1969, the lowest concentrations of silicon were found in surface samples taken at the southern end of the lake (Schelske and Callender 1970). Powers and Ayers (1967) found the lowest concentrations of silicon at Chicago in an analysis of records kept for municipal water intakes. The Chicago records, as well as those from other areas, show decreasing concentrations with time (Fig. A-6).

Abundant plankters of certain taxa have caused problems for water supply around southern Lake Michigan. Dinobryon has been cited as the cause of "fishy" odor in the Chicago water supply (Baylis 1951). Tabellaria, and several other genera of diatoms, have caused problems of filter-clogging (Baylis 1954, 1957, 1960). Two diatoms not previously reported from Lake Michigan, Stephanodiscus hantzschii and S. binderanus (M. binderana?) have become abundant enough at the Chicago intake to cause further filter clogging problems in recent years (Vaughn 1961).

Blooms and filter clogging by S. hantzschii, and perhaps also S. binderanus, were correlated with periods when a fine turbidity occurred in raw and finished (filtered) water. This turbidity was caused by small cuboidal crystals of calcium carbonate and the conclusion reached was that it was caused by the diatom blooms. It was surmized that the dense blooms used up available free CO_2 and then used bicarbonate as a CO_2 source, resulting in the precipitation of carbonate. This theory was supported by observed changes in pH and alkalinity (Vaughn 1961).

Ayers, Stoermer and McWilliam (1967) observed "milky water" in several cruises on five cross-lake transects between Chicago and Frankfort, Michigan. They found some evidence that this condition occurred periodically as far back as 1954 but suggested that it had become more pro-

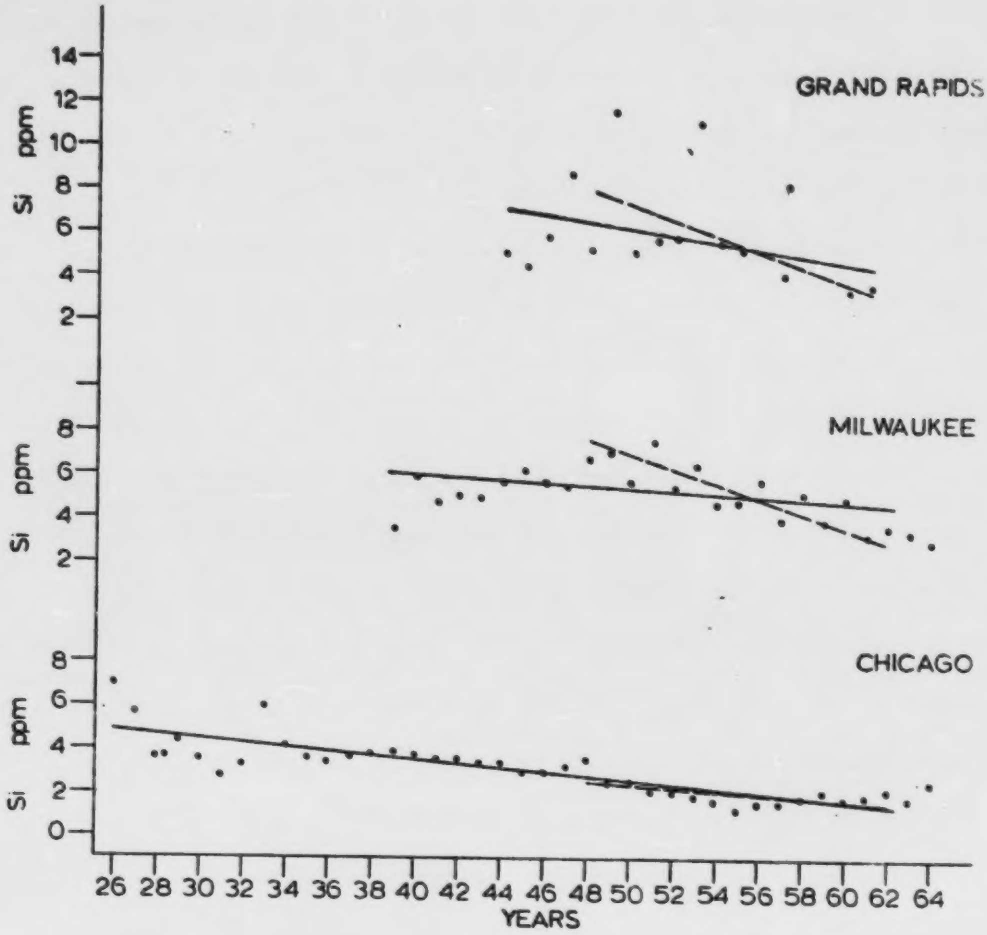


Figure A-6. Silica concentration at water intakes of Grand Rapids, Milwaukee, and Chicago plotted against time for the periods of existing records. (Figure taken from Powers and Ayers 1967.)

nounced in the period 1964-1966. "Milky water" was again observed at stations off Chicago in the summer of 1969 (Schelske and Callender 1970). Ayers, Stoermer and McWilliams hypothesized that the cause of this turbidity was fine particles of calcium carbonate formed when diatoms used bicarbonate as a CO_2 source. The situation is thus possibly the same as that observed by Vaughn (1961) and illustrates again that phenomena observed in degraded inshore waters may be anticipated soon the open lake if eutrophication continues at its present rate. We have, in the southern end of the lake, a large-scale nutrient enrichment experiment and to use the terms chosen by C. H. Mortimer (discussion to Schelske and Stoermer 1972) the Chicago intake might be considered a useful "early warning system".

Phytoplankton abundance in Lake Michigan, even in southern Lake Michigan, is low compared to Lake Erie. There is no doubt that phytoplankton would increase in abundance with accelerated eutrophication and that, consequently, problems of objectionable tastes and odors and filter-clogging would become more frequent and more severe. This would be particularly true if, as has been predicted, further inputs of phosphorus result in depletion of silica by excessive diatom growths and the flora shifts to one dominated by glue-green algae. Blue-greens are typical of eutrophic situations and are notorious for creating taste and odor problems and the clogging of filters.

Macroscopic Algae

According to the FWPCA (1968a), the Chicago Park District has, for several years, experienced problems with fouling of beaches by algae washed in from the lake. In 1961, the offending organism at Oak Street and Montrose beaches was found to be *Dichotomospiphon*, a green filamentous alga. In 1962 the green alga *Cladophora glomerata* was the principal species involved but *Oedogonium* was also present (FWPCA 1968a). All of these organisms require a firm substrate and thus do not grow on the beach but are washed up there when luxuriant growths are broken loose during heavy weather. The resulting windrows of algae become foul-smelling after a few days in the summer heat. Flies and other insects become very abundant in the decaying masses (FWPCA 1968a). The unesthetic appearance of the decaying algae, as well as the resultant odor and swarms of insects, obviously detract from the recreational value of the beaches.

Cladophora has, since the 1950's become an important algal nuisance in lakes Erie and Ontario as well as in southern Lake Michigan. Herbst (1969) reported *Cladophora* very abundant (problem conditions) near Milwaukee, Racine, Kenosha, Chicago, Michigan City and Benton Harbor. He found only sparse growths, small in extent, along northern shores of Lake Michigan.

The distribution of *Cladophora* is correlated with nutrient-rich water, it being rare in the upper lakes except near centers of population. Herbst (1969) considered phosphorus to be the limiting nutrient in most situations. Application of phosphorus to suitable locations in Lake Huron, which were otherwise devoid of *Cladophora*, resulted in its establishment and subsequent growth (Neil and Owen 1964). Mechanical removal and the use of algicides have effected temporary control of Cladophora in local situations (McLarty 1961). Considering the magnitude of the problem growths, however, and the possible side-effects of applications of biocides, tertiary treatment of effluents for phosphorus removal seems the only feasible control measure (Herbst 1969). We can expect continuing problem growths of Cladophora in direct proportion to the input of nutrients, especially phosphorus.

SEDIMENTS

Distribution of sediment types

The surficial bottom sediments of Lake Michigan have been described by Hough (1935), Ayers and Hough (1964), Ayers (1967), Powers and Robertson (1967, 1968), Somers and Josephson (1968),Mozley and Alley (1973) and other authors. Of interest in the present context are comments on the distribution of sediment types in the southern end of the lake as this may have some bearing on consideration of the distribution and sampling of benthic invertebrates. Reports of contamination of sediments are, of course, also of value. The following discussion will thus rely heavily on those few papers which provide the greatest detail in describing the sediments of the southern end of the lake.

Ayers (1967) reported on the distribution of sediment types as based on a "Field description" at the time of collection. He recognized 12 categories of sediment, mostly on the basis of texture. Figure A-7, taken from Ayers' paper,shows that sediments of the southwestern corner of the lake range from silty sand to till, with fine to coarse sands covering most of the area.

Somers and Josephson (1968) published a paper based upon mechanical analysis of the same samples described by Ayers (1967). They include a map of sediment distribution patterns which is essentially identical to Figure A-7 , except that they have lumped Ayers' several classes of sand, silt and clay under these three simple headings. For the area of our concern conclusions remain the same; bottom sediments are "hard" over most of the area, consisting largely of sand with small areas of gravel and till.

Explanation of symbols used in Figure A-7
on facing page. From Ayers (1967).

◐	No Sample (Hard Bottom?)
●	Till
○	Gravel (Granules to Boulders)
◩	Coarse to Very Coarse Sand
■	Medium Sand
□	Very Fine to Fine Sand
⦸	Silty Sand
⊘	Clayey Sand
△	Sandy Silt
▲	Sandy Clay
▼	Silty Clay
▽	Clayey Silt
◆	"Clay"

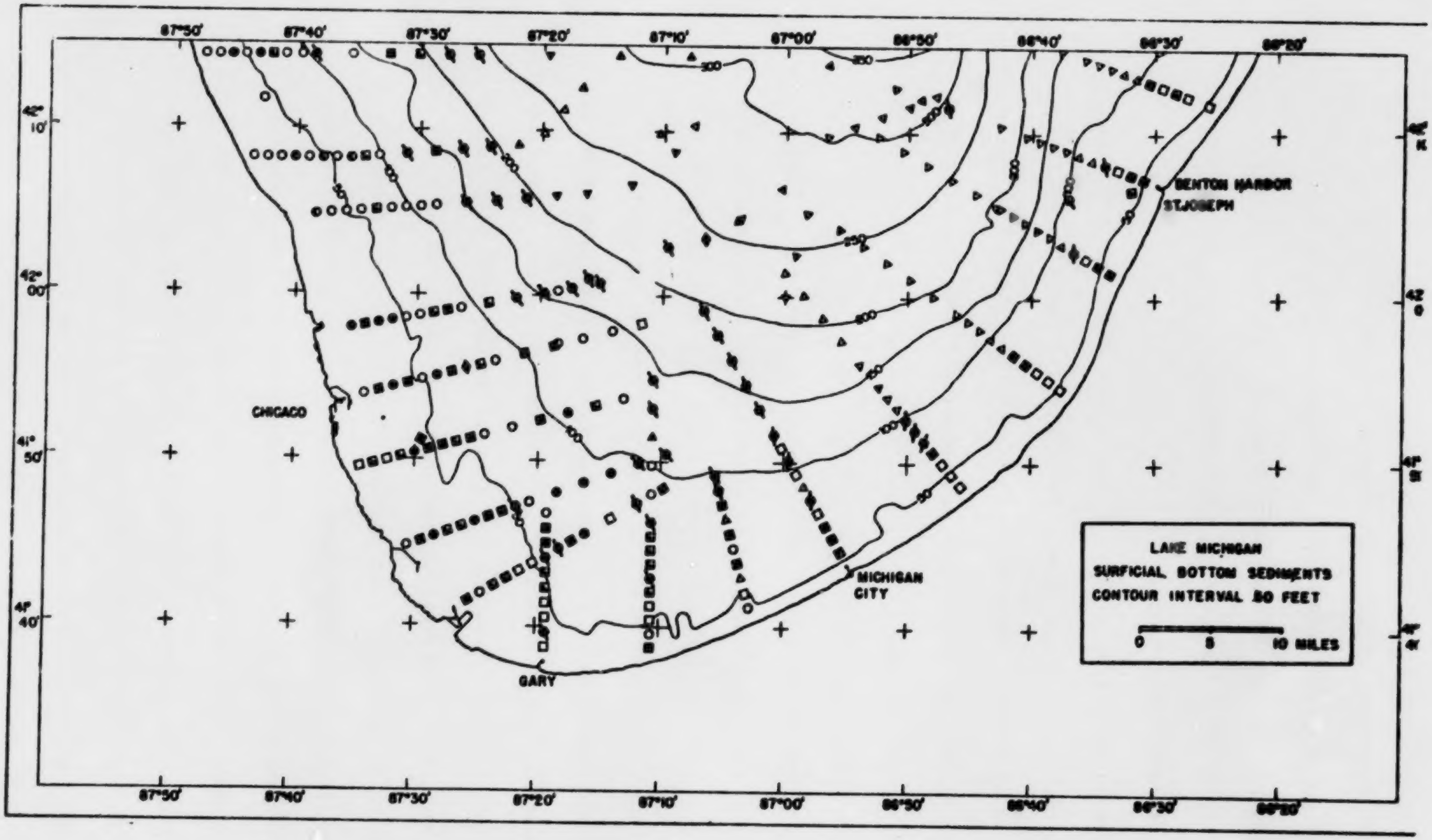

LAKE MICHIGAN
SURFICIAL BOTTOM SEDIMENTS
CONTOUR INTERVAL 50 FEET
0 5 10 MILES
BENTON HARBOR
ST.JOSEPH
MICHIGAN CITY
CHICAGO
GARY
300
250
200
50
87°50'
87°40'
87°30'
87°20'
87°10'
87°00'
86°50'
86°40'
86°30'
86°20'
42° 10'
42° 00'
41° 50'
41° 40'

Figure A-7. Distribution of surficial sediment types in the southern end of Lake Michigan. Symbols are explained on previous (facing) page. Figure taken from Ayers (1967).

Somers and Josephson (1968) also plotted phi median diameter and measures of deviation, and skewness of phi (Inman, 1952) against depth for all transects. In the Chicago-Gary area, in contrast to many parts of the lake, there was no consistent relationship between these measures and depth of distance from shore.

Mozley and Alley (1973) present a map of the distribution of sediment types in the southern end of the lake which is based on Ayers (1967) data as well as additional observations of their own (Fig. A-8). Their map gives less detail and differs in some important respects from that of Ayers (1967). For example, Mozley and Alley indicate that gravel is the dominant sediment type in the inshore area north and west of Gary, Indiana. Ayers' map shows a good deal of sand in this area. Perhaps Mozley and Alley felt that the greater detail of Ayers map was unwarranted since they found that the sediment type at many stations varied from cruise to cruise. For example at one station about 30 km off Gary, Indiana the recorded sediment type was gravel once, fine sand once, silty sand five times, and sandy silt once. This observation may simply indicate lack of precision in locating the station or may reflect periodic movements of surficial sediments in the shallower waters of southern Lake Michigan. The generally poor sorting observed by Somers and Josephson (1968) and comments by these authors and Hough (1935) appear to support the latter explanation. Certainly there are many important sources of sediment along the southern shore of the lake, yet fine sediments are rarely found at shallower depths. Poor sorting and patchiness of sediments in the southern basin may result from a seasonal cycle involving large inputs of finer sediments with spring runoff and temporary deposition of this sediment in shallow areas followed by resuspension and

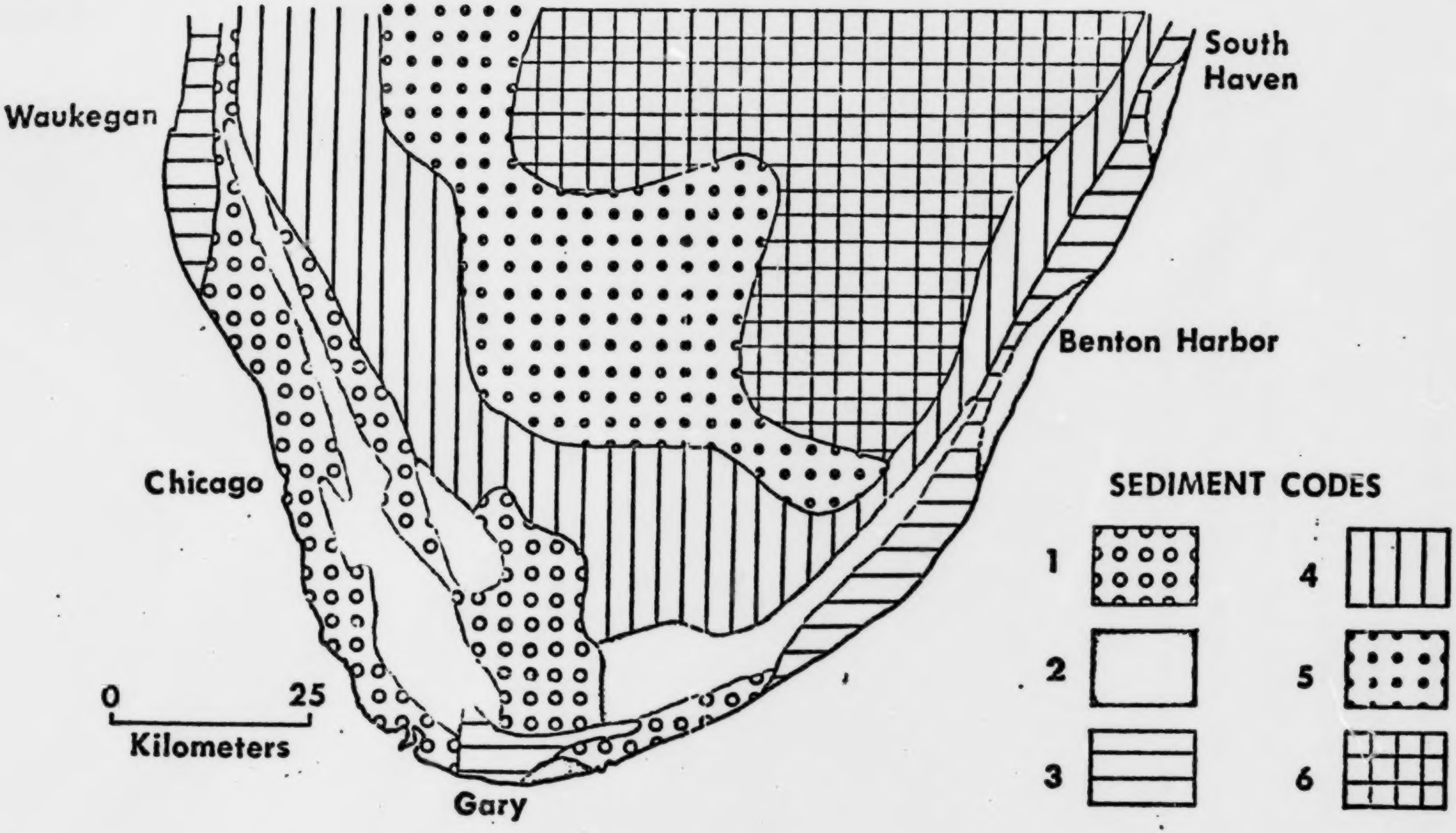

Waukegan
South Haven
Benton Harbor
Chicago
Gary
0
25
Kilometers
SEDIMENT CODES
1
2
3
4
5
6

Figure A-8. Distribution of sediment types in the south end of Lake Michigan according to Mozley and Alley (1973). Sediment codes: 1 = gravel, pebbles; 2 = coarse or medium sand; 3 = clean fine sand; 4 = silty sand; 5 = sandy silt; 6 = silt, clay. Figure taken from Mozley and Alley (1973).

transport to greater depths by storm currents in fall and winter.

The distribution of sediment types in the Calumet-Indiana Harbor area (Fig. A-9) reflects substantial inputs of finer materials by the streams. The silts and clays are found largely at or just off stream mouths. Other areas have coarser sediments, presumably because of removal of finer materials by lake currents.

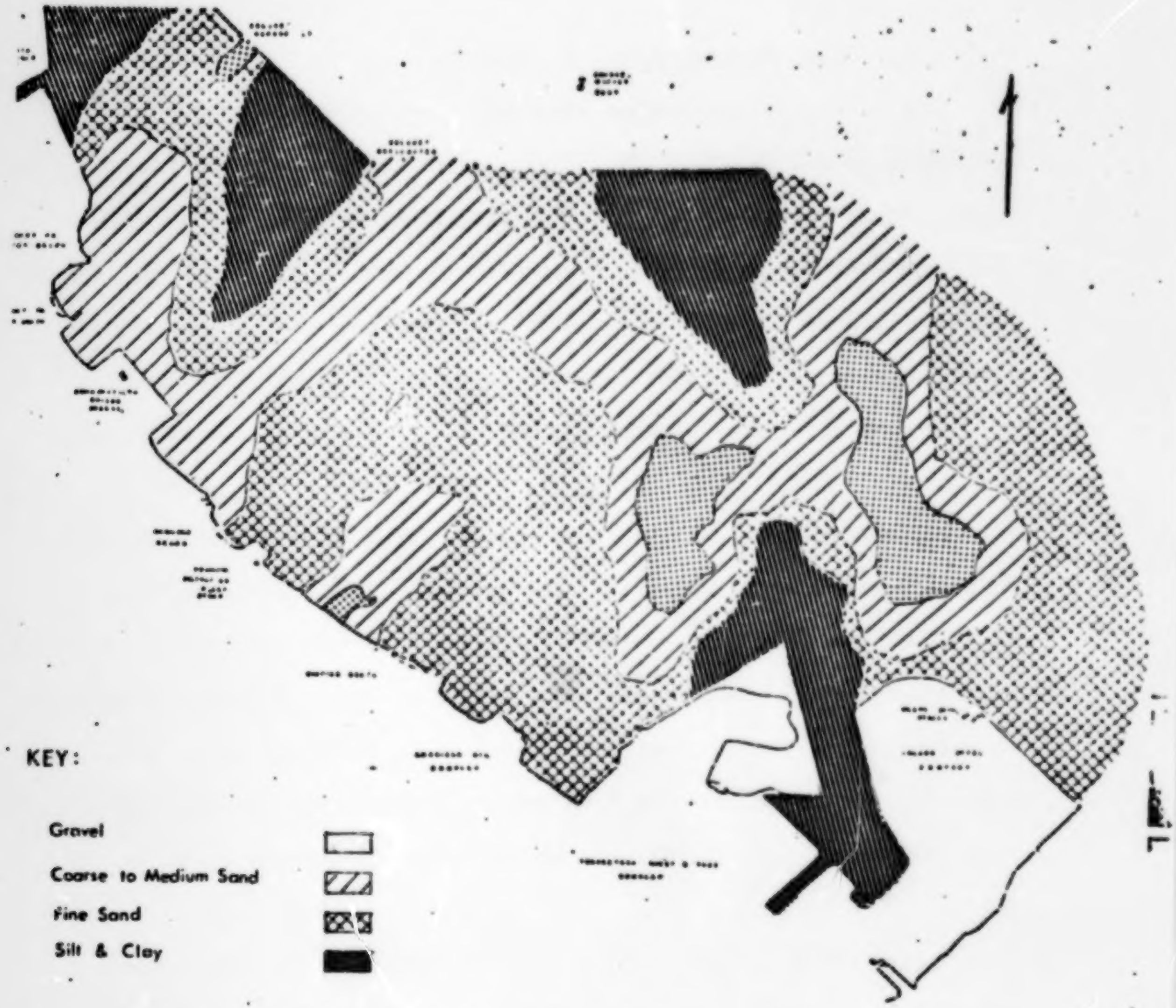

KEY:
Gravel
Coarse to Medium Sand
Fine Sand
Silt & Clay

Figure A-9. Distribution of sediment types in the Calumet-Indiana Harbor area. Based on unpublished data obtained by the FWPCA in 1967.

Evidence of Human Contamination of Sediments

Some of the bottom samples examined by Somers and Josephson (1968) and Mozley and Alley (1973) had an oily odor. This may result from dumping of petroleum products in the lake either directly or through the open-lake disposal of dredging spoils from harbors. Other samples examined by Somers and Josephson (1968) contained cinders, wood, ceramic tile, rusty nails, and other evidence of recent dumping. These authors did not give any further indication of the location or extent of affected sediments.

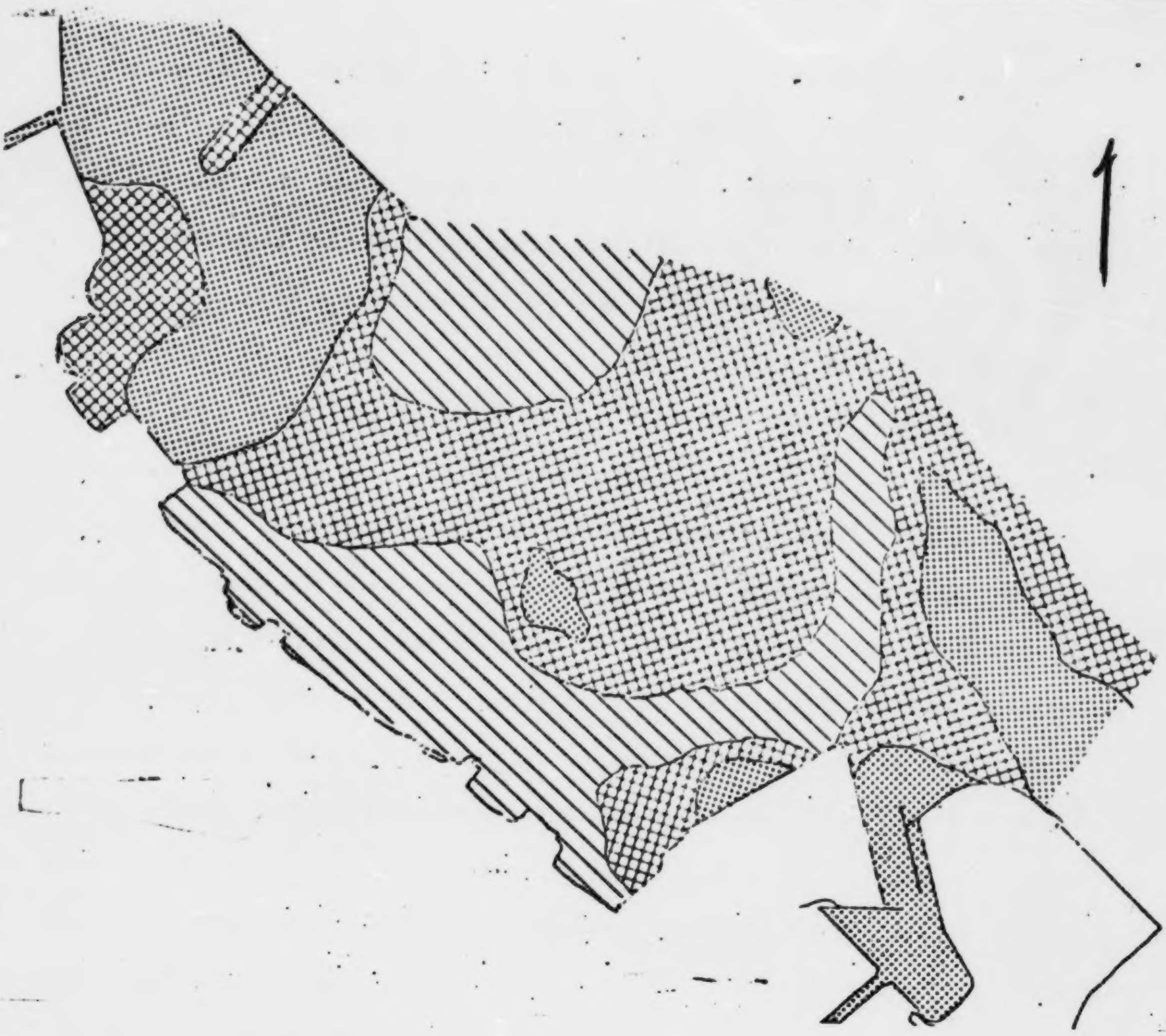
Oil pollution in Lake Michigan occurs primarily at the southern end, originating in the Calumet area. Indiana Harbor canal sediments have been found (June 1967) to have oil and grease contents ranging from 3 to 17% (Johnson _et_ _al_. 1968). The FWPCA (1968) reported that waste discharges in harbors along the southern shore resulted in sediments which were inhibitory to the establishment of benthic organism populations. They referred specifically to oil, grease, and allied petroleum wastes as the source of the problem.

Mozley and Alley (1973) reported that comparison of oily samples and non-oily samples from the same Lake Michigan stations revealed no strong or consistent effect on the benthos, though in a few such cases oligochaetes made up a larger percentage of the fauna in the oily sample.

Gannon and Beeton (1969, 1971) pursued this problem through laboratory investigations, using sediments from nine Great Lakes harbors. In selectivity tests _Pontoporeia_ _affinis_ avoided Indiana Harbor sediments and displayed a lower preference for Calumet Harbor sediments when compared to sediments from an unpolluted harbor and the open lake. In viability tests, Calumet and Indiana harbors were among the five harbors whose sediments caused greatest mortality of P. affinis. Gannon and Beeton (1969, 1971) concluded that sediments from these harbors were so toxic that dredging spoils should not be dumped in the open lake. While they did not attempt to identify the toxic substance(s) involved, the Calumet and Indiana Harbor samples used in the tests were obviously polluted with oil.

Shimp, Leland and White (1970) and Shimp et al. (1971) have studied the vertical distribution of trace elements in cores taken in southern Lake Michigan. In many cores, concentrations of bromine, chromium, copper, lead and zinc, were much higher in the upper few centimeters than at greater depths in the cores. Patterns of concentration with depth suggest continuing increases in deposition of these trace elements. On a geographical basis, highest concentrations in the most recent sediments were generally off Grand Haven or Benton Harbor, Michigan. Except for zinc, and chromium at a few stations, concentrations in the Calumet area were not particularly high when compared to the southern basin as a whole. Shimp and co-workers (1970, 1971) did not look for biological effects of accumulation of these trace elements, and other research on the benthos of the open lake has given no indications that any have built up to harmful levels.

In the immediate area of Calumet and Indiana Harbors there are high concentrations of many pollutants, several of which could have been responsible for the toxicity observed by Gannon and Beeton (1969, 1971). The distribution pattern strongly suggests that the pollutants enter in the two tributary streams (Fig. A-10).



1

GUIDELINES FOR EVALUATING POLLUTED BOTTOM SEDIMENTS

Parameter	Low	Moderate	Heavy
Volatile Solids (%)	0-3	3-6.5	6.5+
Phosphorus (mg/kg)	0-125	125-300	300+
Amonia (mg/kg)	0-25	25-75	75+
Organic Nitrogen (mg/kg)	0-600	601-1500	1501+
COD (mg/kg)	0-30,000	30,000-60,000	60,000+
Oil and Grease (mg/kg)	0-1,000	1,000-2,000	2000+
Iron (mg/kg)	0-8,000	8,000-13,000	13,000+
Lead (mg/kg)	0-20	20-60	60+
Zinc (mg/kg)	0-90	90-200	200+
KEY:	▨	▩	░

Figure A-10. Degree of pollution of sediments in the Calumet-Indiana Harbor area. Based on unpublished data obtained by the FWPCA in 1967.

BENTHIC MACROINVERTEBRATES

Abundance of Major Components of the Lake Michigan Fauna

Numerous studies of the benthos of Lake Michigan have shown that the fauna is dominated by amphipods (*Pontoporeia affinis*) and oligochaete worms (most importantly *Stylodrilus heringianus*; Hiltunen 1967, Howmiller 1972). Sphaeriid clams are third in abundance (two genera; 23 species). Other invertebrates; mysids, isopods, leeches, snails, flatworms, roundworms, and midge larvae occur in small numbers.

Many of the benthic studies done on the lake have focused on the distribution and abundance of the dominant elements of the fauna. In an extensive investigation, involving sampling in several months on five cross-lake transects, Powers and Robertson (1965) estimated average numbers of amphipods, and of oligochaetes, and the ratio of the two. Their data indicate that the southern portion of the lake has somewhat lower densities of amphipods, much larger numbers of oligochaetes (Fig. A-11), and amphipod/oligochaete ratios much lower (Fig. A-12) than in other regions of the lake. Verber (1966) cites data of Cook (1965)[1] which reflect similar distributions and says that Cook has reported a significant change in the amphipod/oligochaete ratio in the last 30 years. Robertson and Alley (1966) compared the abundance of dominant benthic organisms in 1964 with the data of Eggleton (1931, 1932). They found 1.5 times more *Pontoporeia*, 2.6 times more oligochaetes, and 4.3 times more sphaeriids in 1964. Thus the amphipod/oligochaete abundance ratio decreased, on the average, to

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[1] Cook's report was not available to me, and is apparently unpublished.

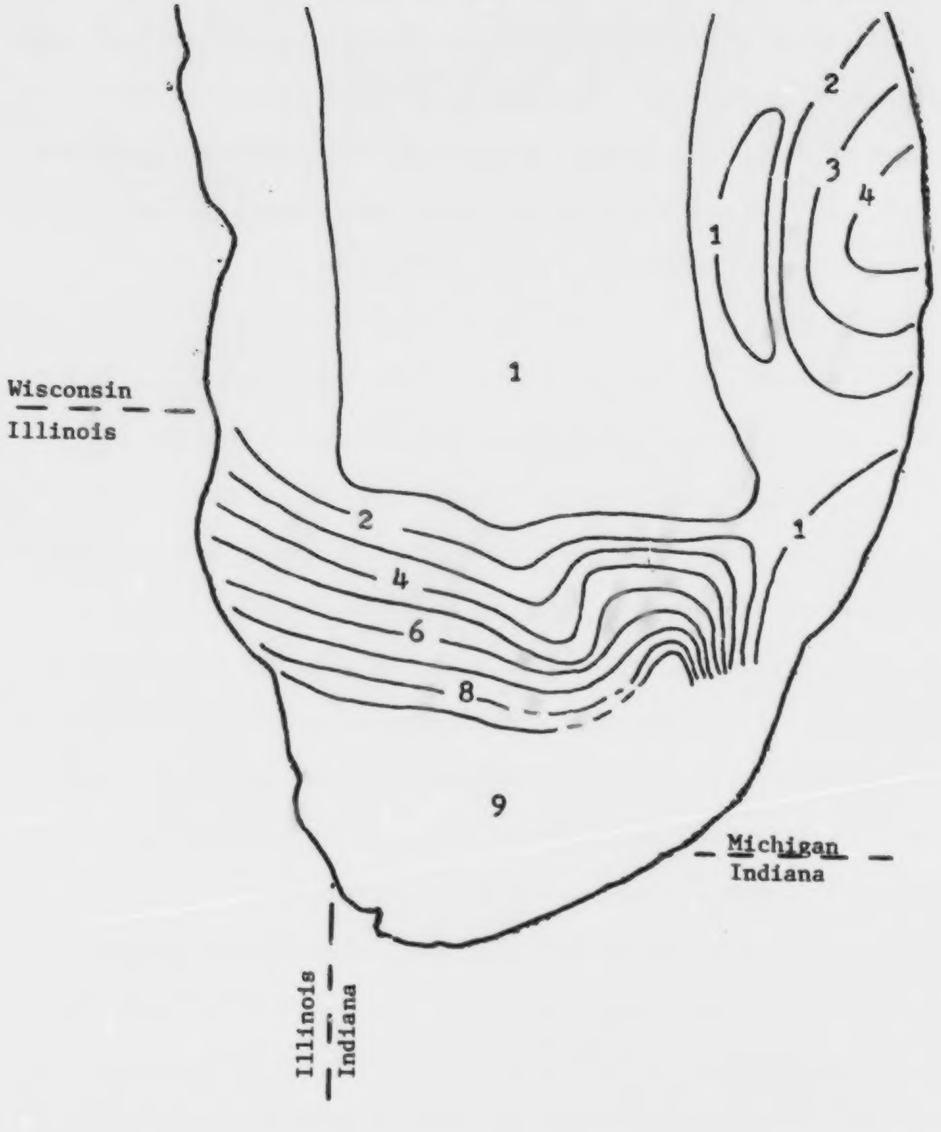
2
3
4
1
1
Wisconsin
Illinois
2
4
6
8
1
9
Michigan
Indiana
Illinois
Indiana

Figure A-11. Average numbers of oligochaete worms, 1000's/m^2, August - November 1964, in the benthos of Lake Michigan south of Milwaukee-Grand Haven. (After Powers and Robertson 1965).

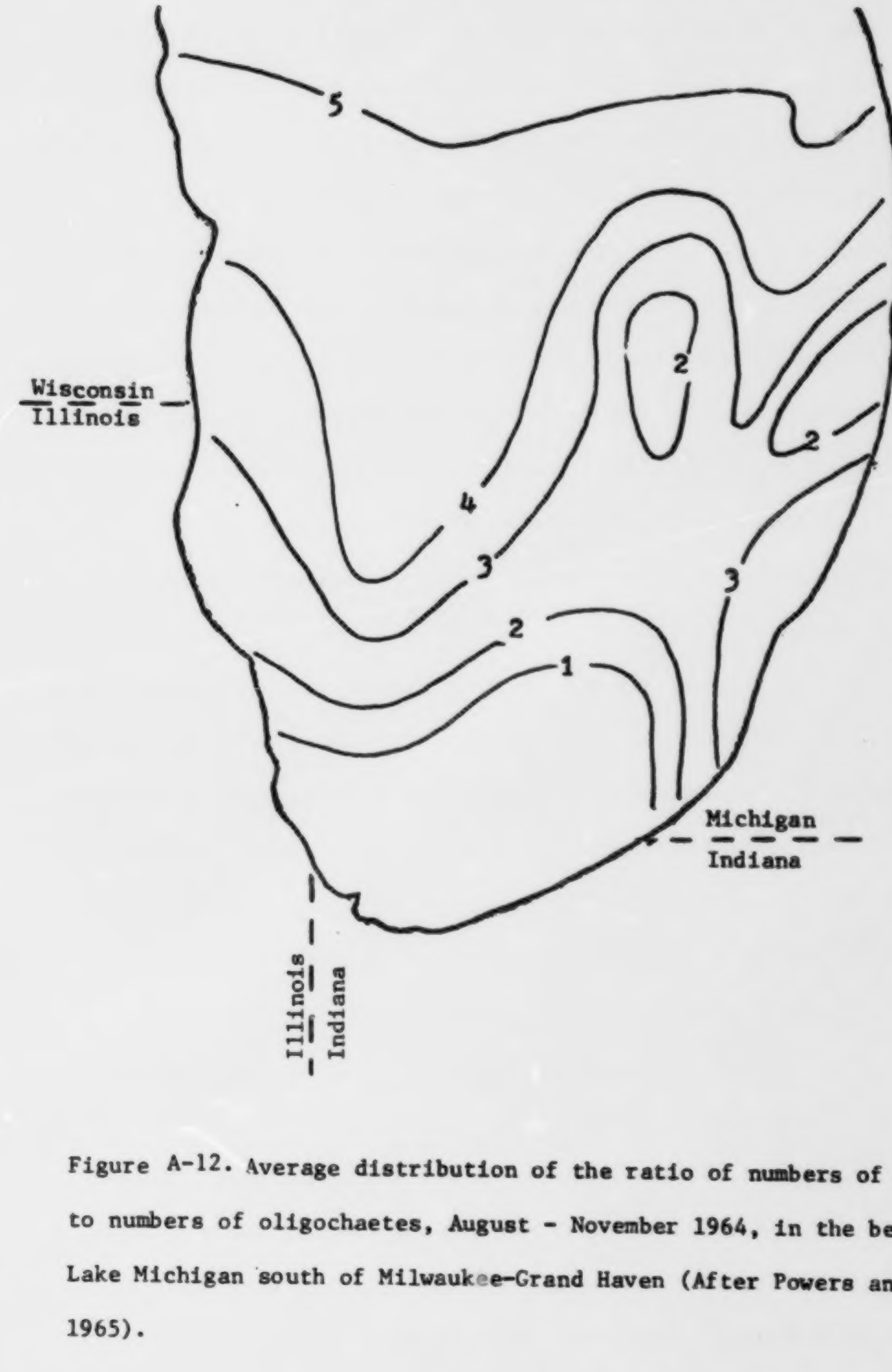
5
4
3
2
2
2
1
3
Wisconsin
Illinois
Michigan
Indiana
Illinois
Indiana

Figure A-12. Average distribution of the ratio of numbers of amphipods to numbers of oligochaetes, August - November 1964, in the benthos of Lake Michigan south of Milwaukee-Grand Haven (After Powers and Robertson 1965).

about 0.6 of the value in 1931-32.

There seems to be an implication in the comments of Verber (1966) that the amphipod/oligochaete ratio has significance as an indicator of environmental quality, and that the reported change in this ratio reflects some deterioration of the lake. This opinion is given support by the results of Robertson and Alley, since a decrease in the value of the ratio occurred concurrently with an increase in standing crop of benthos which probably reflects increased productivity of the lake. This is rather indirect reasoning, however, and we have no understanding of why the dominant oligochaetes of the lake should increase relative to amphipods as a result of eutrophication, especially when we consider the fact that *Stylodrilus* is generally considered to be an indicator of oligotrophic conditions in the Great Lakes.

A report by the Federal Water Pollution Control Administration (FWPCA 1968a) summarized studies done in 1962-1964. They found extensive areas of high oligochaete ("sludgeworm") abundance off southern and southwestern shores of the lake. They considered worm densities exceeding 1000/m^2 to be indicative of pollution (Wright 1955, Surber 1957) and, using this criterion, identified a 2100 square mile area of polluted conditions in southern Lake Michigan (Fig. A-13). Pollution of this large area was attributed to inputs from the large metropolitan areas on the southern and southwestern shore (FWPCA 1968a).

Shallow areas near the southern tip of the lake had lower numbers of amphipods than comparable areas along eastern and western shores. The area of low amphipod density coincided, at least partly, with areas which held >2000 oligochaetes/m^2 (Fig. A-14 ,FWPCA 1968a).

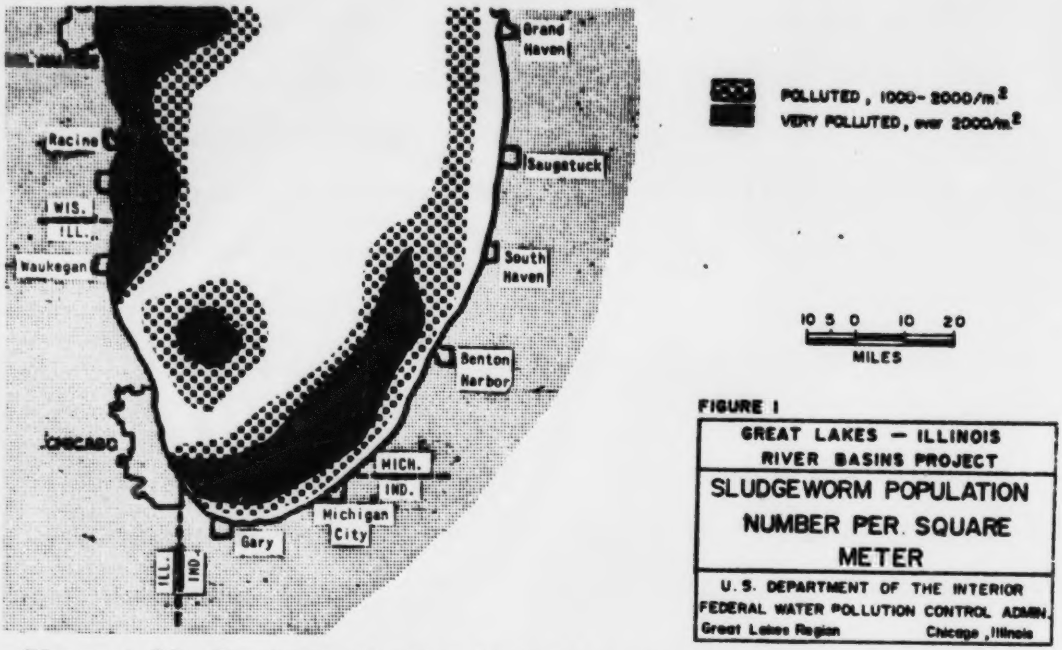
Grand Haven
MILWAUKEE
Racine
WIS.
ILL.
Waukegan
Saugatuck
South Haven
Benton Harbor
CHICAGO
MICH.
IND.
Michigan City
Gary
ILL.
IND.
POLLUTED, 1000-2000/m²
VERY POLLUTED, over 2000/m²
10 5 0 10 20
MILES
FIGURE 1
GREAT LAKES — ILLINOIS RIVER BASINS PROJECT
SLUDGEWORM POPULATION NUMBER PER SQUARE METER
U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN.
Great Lakes Region
Chicago, Illinois

Figure A-13. Abundance of oligochaete worms in the benthos of southern Lake Michigan, 1962 (From FWPCA 1968a).

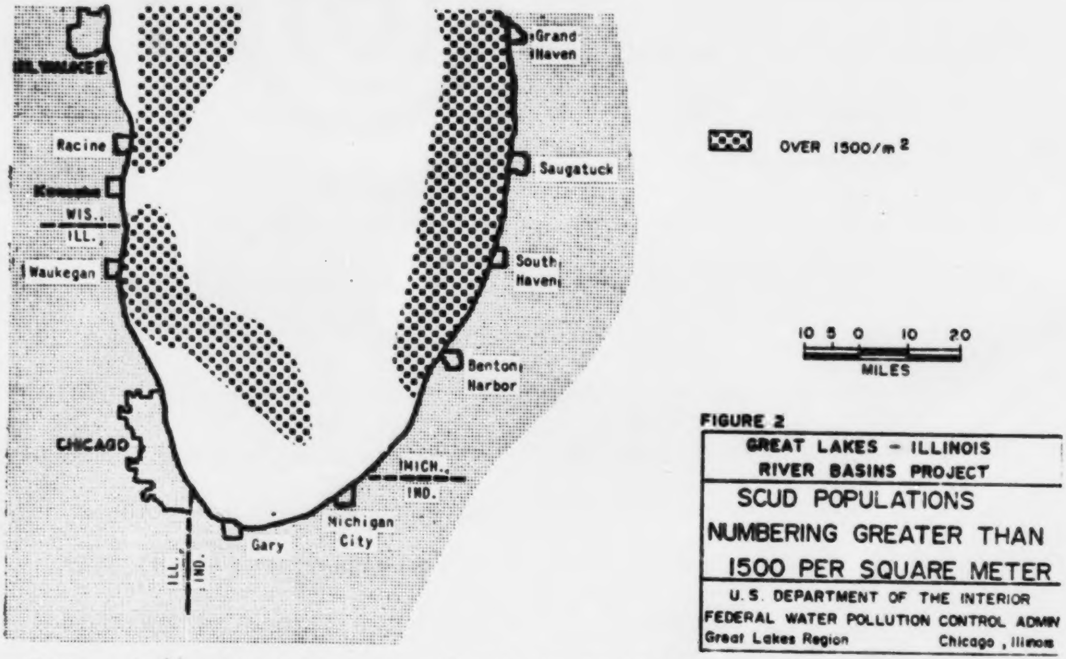
MILWAUKEE
Grand Haven
Racine
Kenosha
WIS.
ILL.
Waukegan
Saugatuck
South Haven
Benton Harbor
CHICAGO
MICH.
IND.
Michigan City
Gary
ILL.
IND.
OVER 1500/m²
10 5 0 10 20
MILES
FIGURE 2
GREAT LAKES — ILLINOIS RIVER BASINS PROJECT
SCUD POPULATIONS NUMBERING GREATER THAN 1500 PER SQUARE METER
U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN
Great Lakes Region
Chicago, Illinois

Figure A-14. Abundance of amphipods in the benthos of southern Lake Michigan, 1962 (From FWPCA 1968a).

Mozley and Alley (1973) present a more detailed picture of the differences in numbers of these organisms in the central and southern basins of the lake (Table A-1). Average abundance of amphipods was greater in the central basin at all depths but the difference was greatest at depths of 40 m or less. Oligochaetes were more abundant in the southern basin at depths of 40 m or less. At greater depths (40 - 140 m) there was no striking difference between the two regions of the lake (Table A-1).

Areas where Mozley and Alley (1973) found average abundances of 1000 or more oligochaetes per square meter were approximately the same as those found by the FWPCA (Fig. A-13). They found, however, much larger areas of high amphipod abundance and attribute the difference to the fact that different samplers were used. The FWPCA used the Petersen grab while Mozley and Alley used a Ponar. The Petersen, as built and sold in the U.S., has solid surfaces in the tops of the jaws and thus a hydraulic disturbance forms ahead of the grab as it is lowered. Such a hydraulic disturbance ("shock wave") can serve as a directional signal allowing very motile animals to escape and can even blow away fine surficial sediments with their resident animals (Wrigley 1967). Since amphipods live near the sediment water interface ("epifauna") and are capable of swimming, they would understandably be more seriously affected by a hydraulic disturbance than the slowly burrowing oligochaetes which are more typically found deeper in the sediments ("infauna"). The Ponar, having screened tops in the jaws, creates less of a hydraulic disturbance and can thus provide a more realistic estimate of amphipod abundance.

TABLE A-1. Comparison of the abundances of Amphipoda and Oligochaeta between the central and the southern regions of Lake Michigan by depth zones, 1964-67. $\bar{X}$ = mean; $S_{\bar{X}}$ = standard error; N = number of observations (single grab samples) (From Mozley and Alley, 1973).

Taxon	Depth Zone	Central Region			Southern Region		
		$\bar{X}$	$S_{\bar{X}}$	N	$\bar{X}$	$S_{\bar{X}}$	N
Amphipoda	0-20m	6,380	828	12	2,544	216	235
	21-40m	8,477	286	199	4,264	301	160
	41-60m	6,876	294	116	4,858	177	164
	61-140m	3,353	86	286	3,137	86	250
Oligochaeta	0-20m	1,389	727	10	2,898	346	229
	21-40m	1,460	83	196	3,411	281	157
	41-60m	2,509	307	91	2,171	109	163
	61-140m	520	29	227	720	49	248

While Mozley and Alley (1973) did find higher numbers of oligochaetes in the southern basin than in the central basin (at depths < 40 m), they failed to confirm the picture of generally extreme abundance ($> 9000/m^2$) reported by Robertson and Alley (1965). Mozley and Alley (1973) analyzed data from many more stations in the southern basin and we may take theirs as the more representative of the two sets of data.

Mozley and Alley also found that, generally, benthic biomass at a given depth declined south of the latitude of Benton Harbor. This indicates that increase in oligochaetes did not equal the geographical decrease in amphipods. They suggest that this is because of the preponderance of coarse sediments in this area. Since oligochaetes prefer fine sediments, the effect of the large areas of sand and gravel would counteract the tendency for higher pollution levels to elevate oligochaete abundance. Mozley and Alley (1973) suggest that interuption of the band of high oligochaete abundance shown in the Chicago area by the FWPCA (Fig. A-13) was due to the frequent occurrence of coarse sediments in that area, rather than to lower levels of pollution. They conclude that, because of the lack of permanent deposits of fine sediments and the difficulty of collecting grab samples from rocky bottoms, oligochaete abundance cannot serve well as an indicator of pollution in the Chicago agea.

In the discussion so far, we have made the point that the abundance of the two major elements in the benthic fauna; amphipods and oligochaetes, and the ratio of their abundances are considered to have some value as indicators of environmental quality. There is evidence that abundance of both these groups has increased, and the ratio amphipods/oligochaetes has decreased in recent years; presumably indicating that eutrophication is proceeding at a perceptable rate.

We have seen, however, that attempts to estimate the abundance of these organisms is affected by the selection of sampling gear, and that physical features of the environment may modify the effect of a given level of pollution or eutrophication upon abundance of benthos. Furthermore, whatever indicator value exists in estimates of amphipods, oligochaetes, or their ratio, it will certainly not have the same significance in nearshore waters, bays or harbors as in the open lake. This is because, in bays and harbors, amphipods other than Pontoporeia are likely to occur and oligochaetes will be represented largely or entirely by tubificids, some of which are exceedingly tolerant of pollution. In the open lake Pontoporeia is the only amphipod and Stylodrilus accounts for most of the oligochaete fauna. In short, attempts to assess environmental quality through numbers of organisms of major groups are limited in sensitivity and in scope.

The Value of Studies at the Species Level

Analysis of the benthic fauna at the species level appears to offer much more sensitivity for detecting and documenting environmental change than the enumeration of individuals at higher taxonomic levels. I am not referring here to indicator species in the sense that simple presence or absence has any significance. Rather it is the relative abundance of species varying in pollution tolerance that offers greatest promise in comparing environmental quality between locations or over time in a particular area. To do this correctly requires identification of all organisms to the fullest extent possible. Judgements may then be made on the basis of the proportion of each species and what is known of its environmental requirements. It is not satisfactory to simply list numbers of pollution tolerant and intolerant organisms. Without identification to the species level, reinterpretation of the data on the basis of new knowledge of environmental requirements is not possible. Reports with results expressed in this manner also leave the impression, probably generally correct, that the organisms were, in fact, not really identified.

In practice, few studies have attempted complete identification of all organisms found. This is because most studies are done by one or a few people whose taxonomic competence is limited. Also, some groups are less valuable than others for these purposes; because they lack ecological differentiation in the Great Lakes or because we have, as yet, a very incomplete knowledge of their environmental requirements.

As previously mentioned, there is general agreement that *Pontoporeia affinis* is a clean water organism. It is also commonly considered to be a cold stenotherm (Henson 1966), although it exists in Lake Michigan at temperatures ranging from 1-19 C (Alley 1968). While high densities of *Pontoporeia* may be considered good evidence of unpolluted conditions, low densities do not necessarily reflect pollution but may be related to other environmental factors (Alley 1968) or, as pointed out earlier, can simply reflect a poor choice of sampling gear. Other species of amphipods are very rare in the lake, but may occur in bays or harbors; e.g. Howmiller and Beeton (1971) reported *Hyalella azteca*, *Gammarus fasciatus*, and *Crangonyx* sp. as well as *P. affinis* from Green Bay.

Sphaeriid clams are an important group in the benthos of the lake. At least 23 species are present (Henson and Herrington 1965, Robertson 1967) but little use has been made of them in environmental surveillance.

Chironomidae larvae have long been employed in the classification of aquatic habitats (cf. Brundin 1949, 1958) but have been little utilized in this respect in Lake Michigan. This is probably because they are a quantitatively unimportant element in the benthos of the lake; comprising about 1% of the deep water benthos (Powers and Alley 1967) and little more (4%; Mozley and Garcia 1972) of shallower benthic assemblages. In bays and harbors, however, they constitute a larger proportion of the fauna (26% in Green Bay; Howmiller and Beeton 1971) and may play a useful role in environmental assessment in these situations (Howmiller and Maass 1973).

Oligochaete worms appear to offer particular promise for the bioassessment of environmental quality in Lake Michigan. They are found in bottom samples from all parts of the lake, including bays and harbors, and, except on very coarse substrates, are relatively abundant. Furthermore, more than forty species are known from the lake, and these have a considerable range of environmental preferences. Recent studies (Hiltunen 1967, Brinkhurst, Hamilton and Herrington 1968, Howmiller and Beeton 1970) of species distributions with respect to water quality have allowed a classification of some species according to their indicator value (Table A-2).

Benthic Studies in the Calumet Area

Against the background of some general knowledge of the Lake Michigan bottom fauna, and of the differences in utility of studies at various taxonomic levels, we can review the few studies done to date in the Calumet area.

Table A-2. Classification of some Lake Michigan oligochaetes according to the degree of enrichment or pollution of the environment (from Mozley and Howmiller 1973).

I. Largely restricted to unpolluted oligotrophic situations ("saprophobes").

Stylodrilus heringianus
Pelvoscolex variegatus
P. superiorensis
Limnodrilus profundicola
Tubifex kessleri
Rhyacodrilus coccineus
R. montana

II. Species characteristic of areas which are mesotrophic or only slightly enriched.

Peloscolex ferox
P. freyi
Ilyodrilus templetoni
Potamothrix moldaviensis
P. vejdovskyi
Aulodrilus spp.

III. Species tolerating extreme enrichment or organic pollution (saprophiles and saproxenes, see also IV).

Limnodrilus hoffmeisteri
L. udekemianus
L. angustipenis
Tubifex tubifex

IV. Species restricted to areas of gross organic pollution (saprobionts).

Limnodrilus cervix
L. claparedeianus
L. maumeensis
Peloscolex multisetosus

The FWPCA (1968a) reported that sludgeworms and sphaeriid clams were dominant in the benthos along the southern shore of the lake (Calumet Harbor to Burns Ditch). They felt that the area was "extensively degraded biologically in degrees ranging from severe near Indiana and Calumet Harbors to less severe near Burns Ditch."

According to the FWPCA (1968a) the degradation of the benthic community extended out as far as twenty miles and the total area affected by wastes discharged from the Chicago-Calumet area covers 2100 mi^2. This latter judgement is based on the high sludgeworm abundance in the area shown in Fig.A-12. The relatively low population density of amphipods in the southern tip of the lake was said to be caused by toxic wastes discharged in the Calumet area. This, of course, is simply speculation. As has already been indicated, the sampling gear used by the FWPCA will almost certainly underestimate amphipod abundance, and the effectiveness of their sampler (Petersen grab) varies greatly with depth and substrate type (Beeton, Carr and Hiltunen 1965). The lower density of amphipods is also possibly a reflection of the shallowness of this region of the lake and the normal depth distribution of Pontoporeia (Alley 1968, Mozley and Alley 1973). Lastly, the FWPCA (1968a) provides no evidence that amphipods are being affected by any toxic agent nor that any waste addition from the Calumet area is present over such a large area at levels toxic to any organism.

The FWPCA (1967) reported briefly on examination of a few bottom samples taken in Calumet Harbor, Indiana Harbor, and tributary canals in 1965 and 1966. Results are not quantitative and organisms are identified only to major groups (Table A-3). Nevertheless, they clearly convey the impression that the harbors and immediate tributaries are severely

TABLE A-3. Benthic invertebrates found at stations in Calumet Harbor, Indiana Harbor and tributary canals in 1965 and 1966 (From FWPCA 1967).

Area	FWPCA Station Number	Date	Benthic Invertebrates
Grand Calumet River	1	1965	None
" " "	1	1966	None
Indiana Harbor Canal	2	1965	None
" " "	2	1966	Sludgeworms[1]
Indiana Harbor Canal	3	1965	None
" " "	3	1966	None
Indiana Harbor	5	1965	Sludgeworms
" "	5	1966	Sludgeworms
Little Calumet River	8	1965	Sludgeworms, bloodworms[2], mayflies
" " "	8	1966	Snails, bloodworms
Calumet Harbor	13	1965	Fingernail clams[3]
" "	13	1966	Fingernail clams, sludgeworms

---

[1] tubificid oligochaetes, [2] chironomid larvae, [3] sphaeriids

polluted. They do not, however, offer the possibility of detecting minor improvement or degradation of the environments as would quantitative data at the species level.

Gagler (1973) examined bottom sediments collected from the Little Calumet River and Burns Ditch. He found no benthos in 12 of 13 samples and only sludgeworms in the other. Chemical analyses indicated highly polluted sediments in these waterways as one would be lead to believe from general paucity of benthic organisms.

Howmiller[1] examined bottom samples taken in shallow water at Bailly, Indiana. Benthic invertebrates were absent, or present in only low abundance, at many stations. This was attributed to the fact that most stations were on hard sand bottoms which, in shallow water and under periodically turbulent conditions, are a physically harsh environment. At only one station out of eight did a sample from a sand bottom in water less than 3 m depth contain benthic invertebrates. Where the bottom contained some silt, animals were found even though the water was only 1.5 m deep. Animals occurred at nine of eleven stations with depths exceeding 4 m.

Oligochaete worms of the family Tubificidae accounted for 52% of the invertebrates found. These included seven recognizable taxa; *Aulodrilus pluriseta*, *Limnodrilus cervix*, a form morphologically intermediate between *L. cervix* and *L. claparedeianus*, *L. hoffmeisteri*, *Peloscolex multisetosus*, *Potamothrix moldaviensis*, and *P. vejdovskyi*, and a large proportion of unidentifiable sexually immature forms (Table B-4). The worm fauna is thus composed of a mixture of forms tolerant of enrichment or pollution and some normally restricted to heavily polluted areas (Table A-3).

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[1] Howmiller, R. P. 1970. A Report on Benthic Invertebrates from the Bailly, Indiana Region of Lake Michigan. Unpubl. Rept. to Industrial Biotest Laboratories, Inc.

Sphaeriid clams were abundant at two stations and small numbers of chironomid larvae (*Chironomus* cf. *attenuatus*, and *Cryptochironomus* cf. *digitatus*) occurred at most stations. Leeches (*Helobdella stagnalis*) and amphipods (*Pontoporeia affinis*) were present in low numbers at a few stations.

It was concluded that the bottom fauna of this inshore region was dominated by forms characteristic of eutrophic regions, but not of highly polluted regions, of the Great Lakes.

Howmiller[2] also studied the oligochaete fauna of the Calumet and Indiana Harbor region. Specimens examined were from bottom samples taken by personnel of the Metropolitan Sanitary District of Greater Chicago in December 1967 (16 stations) and August 1968 (23 stations). The collections included eleven species of oligochaetes.

Table A-4 compares the composition of the oligochaete fauna in the Calumet-Indiana Harbor region with that in some other shallow areas of Lake Michigan. The comparison suffers from the fact that the studies differed in terms of the size of area, depth range, number of stations and samples, and in the time of the year in which samples were taken. Also, in each case, the areas studied are not homogeneous in sediment and water quality and each includes considerable pattern in terms of worm species distribution. Nevertheless, marked contrast in the composition of these faunas is obvious and correlates well with what we otherwise know of environmental quality in these areas.

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[2] Howmiller, R. P. 1969. The Oligochaeta of the Indiana Harbor-Calumet Harbor Region of Lake Michigan. Unpubl. Rept. to Metropolitan Sanitary District of Greater Chicago.

TABLE A-4. Composition of the oligochaete fauna and relative abundance (percent of total oligochaetes) of species in some shallow areas of Lake Michigan.

Species	Calumet-Indiana[3]		Bailly[4]	Green Bay[5]	Waukegan -Zion[6]	Benton Harbor[7]
	Dec. '67	Aug. '68	Sept. '70	May '67	1970-71	July '70
Stylodrilus heringianus	*				35.0	51.0
Dero digitata				*		
Nais elinguis		*		*		
Slavina appendiculata				*		
Uncinais uncinata					**	
Aulodrilus americanus	*	*		*	**	*
A. pigueti				*		
A. pluriseta	4.8	*	*	*		
Ilyodrilus templetoni				1.1	**	
Limnodrilus angustipenis						*
L. cervix-claparedeianus[1]	1.1	1.4	4.3	3.2	**	*
L. hoffmeisteri[2]	23.3	12.8	*	21.8	**	21.8
L. profundicola					**	*
L. udekemianus	2.8	*		*	**	
Peloscolex ferox				*		
P. freyi		*		2.6		
P. multisetosus	13.1	3.0	*	8.1		
P. variegatus					**	*
Potamothrix moldaviensis	*		9.8	*	**	2.1
P. vejdovskyi	*	*	4.3		**	
Tubifex ignotus					**	
T. tubifex				*	**	
Undetermined immatures; with hair chaetae	1.1	*	6.1	4.6	**	1.7
without hair chaetae	52.9	78.8	74.2	56.8	**	18.5

---

* indicates that species was present but at relative abundance of less than one percent.

** species was present but quantitative data are not available.

[1] Includes counts of *L. cervix*, *L. claparedeianus*, and worms which are intergrades or morphological intermediates.

[2] Includes counts of *L. spiralis*, a species recognized by some Great Lakes investigators but synonomized with *L. hoffmeisteri* by Brinkhurst (1965).

The Calumet-Indiana Harbor fauna is dominated by *Limnodrilus hoffmeisteri*. Mature individuals of this species comprised 23.3% of the December 1967 samples and 12.8% of the August 1968 samples. Like some other tubificids, *L. hoffmeisteri* cannot be positively identified in the immature condition. Immature *L. hoffmeisteri* are thus included among the undetermined immatures without hair chaetae (52.9% in Dec., 78.8% in Aug., Table A-4). Species in these collections which, as immatures, appear similar to immature *L. hoffmeisteri* are other *Limnodrilus* species, *Peloscolex freyi* and *Potamothrix moldaviensis*. Since these are relatively uncommon as mature specimens in the Calumet-Indiana Harbor collections, we can safely assume that almost all the immatures without hairs are *L. hoffmeisteri*. Thus this species, which is tolerant of extreme pollution (Table A-2), comprises approximately 75-90% of the worm fauna in the Calumet-Indiana Harbor region. Second in relative abundance is *Peloscolex multisetosus*, largely or entirely restricted to areas of gross organic pollution in the Great Lakes (Table A-2). The composition of the worm fauna in this region is obviously much like that in Lower Green Bay (Table A-4), an area which vies with the Calumet area for the distinction of being the most severely degraded portion of Lake Michigan (Howmiller 1971, Howmiller and Beeton 1970, 1971).

Footnotes to Table A-4 (cont.)

[3] From data of Howmiller (1969); see footnote p. A-49.

[4] From data of Howmiller (1970); see footnote p. A-50.

[5] From data of Howmiller (1971).

[6] From data of Orenstein, Larson and Lamble (1971).

[7] From data of Mozley and Garcia (1972).

In contrast, the most common species in the samples from the Bailly region is *Potamothrix moldaviensis* (9.8%; Table A-4). Doubtless many of the numerous undetermined immatures without hairs also belong to this "mesotrophic" species. The presence of *P. vejdovskyi* in substantial numbers also indicates that this area is not grossly polluted. From the relative abundance of *Limnodrilus cervix-claparedianus* we can surmize that there is some patchiness within the area studied and that there are places where sediments resemble those found in grossly polluted regions.

The high relative abundance of *Stylodrilus heringianus* (a saprophobe, Table A-2) indicates much cleaner conditions in the Waukegan-Zion and Benton Harbor study areas. Nevertheless, *Limnodrilus hoffmeisteri* accounts for over 20% of the fauna at Benton Harbor. This, again can be attributed to patchiness (commented upon by Mozley and Alley, 1973) and the fact that an environmental gradient exists within the area studied.

Some of the regional variation in composition of the worm fauna *within* the Calumet-Indiana Harbor area can be seen in Figs.A-15 through A-20 which are taken from the report by Howmiller.[1]

Figure A-15shows the relative abundance of worms of the genus *Limnodrilus*, including immatures without hair chaetae, at stations sampled in December 1967. Figure A-16is a similar plot of data from the survey of August 1968.

In this area, the genus includes only species tolerant of, or restricted to, polluted conditions. The distributional pattern (Fig. A-15, 16) clearly reflects the importance of the Indiana Harbor as a source of pollution in this part of the lake. It is difficult to know whether any

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[1] See footnote on p. A-50.

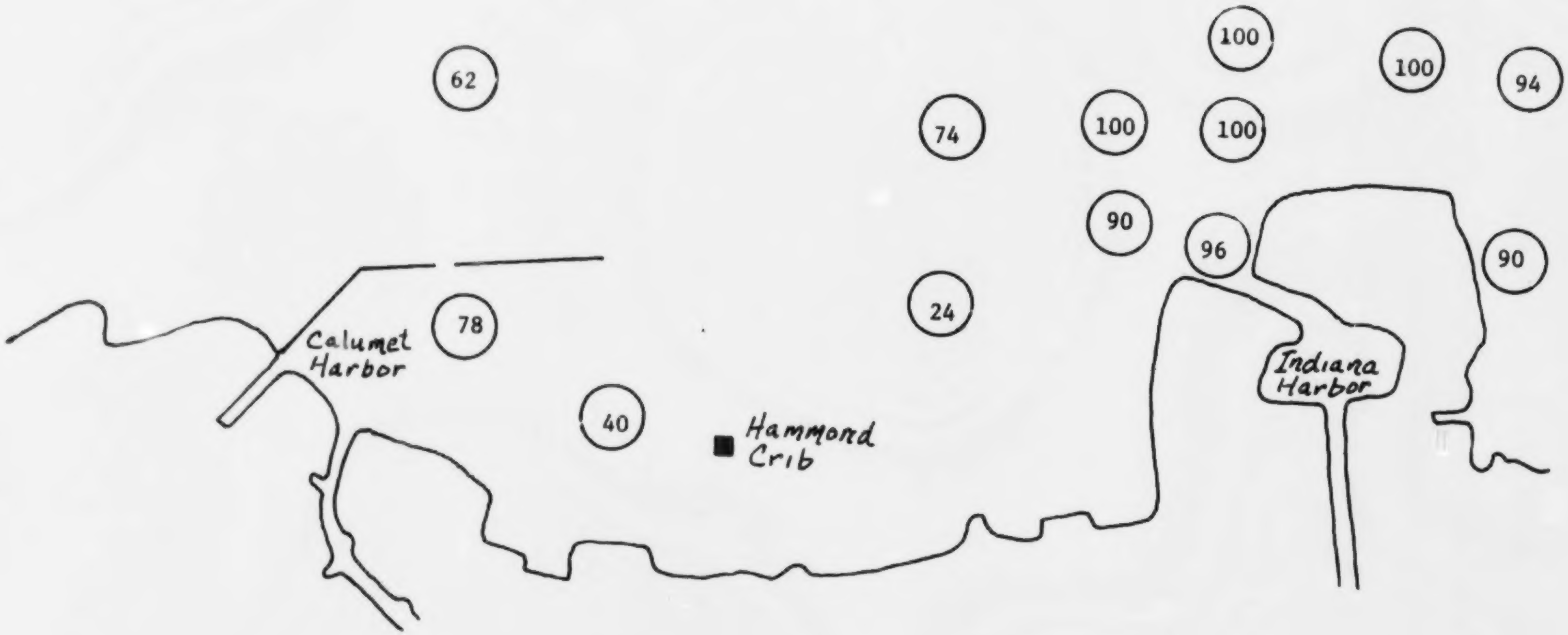
100
62
100
94
74
100
100
100
90
96
90
24
78
Calumet Harbor
Indiana Harbor
40
Hammond Crib

Figure A-15. Relative abundance of worms of the genus Limnodrilus (percentage of all oligochaetes) at stations of December 1967 survey.

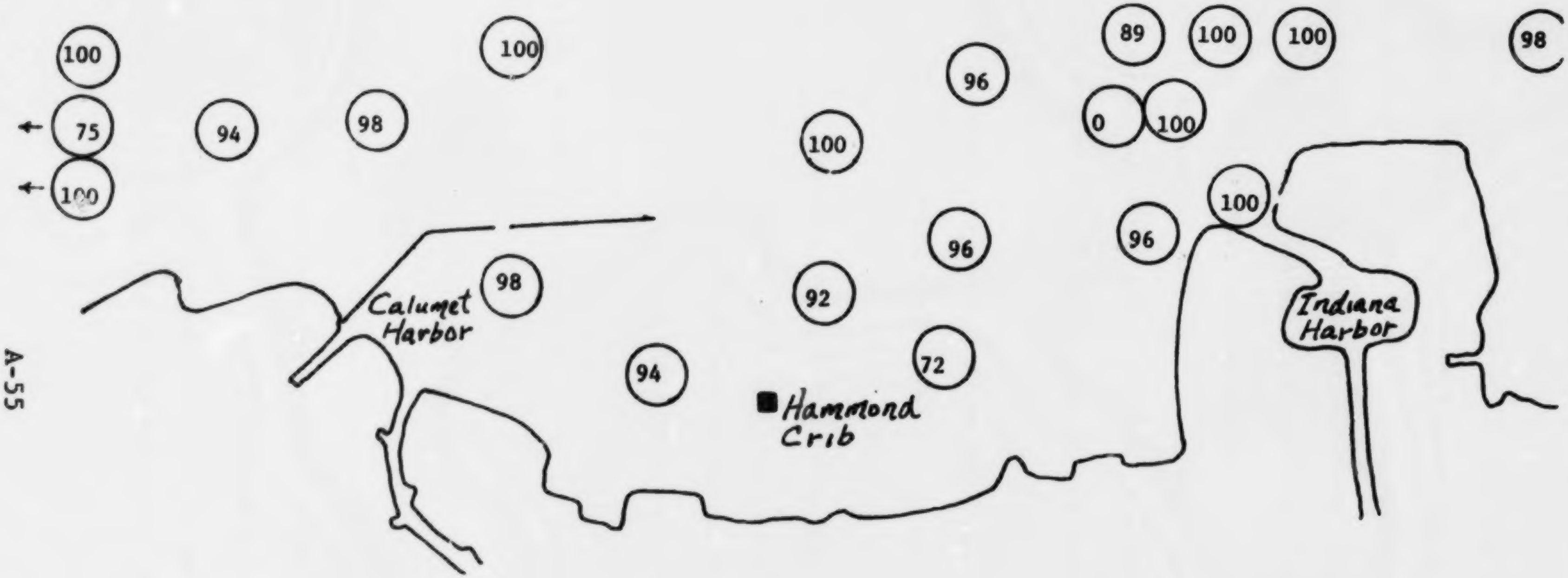
100
75
100
94
98
100
98
Calumet Harbor
94
100
92
Hammond Crib
96
96
72
89
0
100
100
96
100
100
Indiana Harbor
98

Figure A-16. Relative abundance of worms of the genus Limnodrilus (percentage of all oligochaetes) at stations of August 1968 survey.

importance should be ascribed to the difference between the two years, viz. the apparently larger area of very high relative abundance in August 1968. When comparisons are made between years, care should be taken to replicate exact station locations, the season of sampling, and methodology (Howmiller and Beeton 1971). At least the first two criteria are not met in this case, and so the difference between years may be an artifact or may be caused by normal seasonal variation in the numbers of some taxa.

In both 1967 (Fig. A-17 and 1968 (Fig. A-18) the greatest relative abundance of Peloscolex multisetosus was found at some distance from the two polluting inflows and on sediments of "low" or "moderate pollution" (cf Fig. A-10). This is in agreement with studies elsewhere (Brinkhurst 1969, Howmiller and Beeton 1970) which have showed that, while P. multisetosus is favored by pollution, it is not as extremely tolerant as Limnodrilus hoffmeisteri or L. cervix-claparedeianus.

Worms of the genus Aulodrilus, characteristic of slightly enriched areas in the Great Lakes, are here present at a low relative abundance and are conspicously absent from stations near Indiana Harbor (Fig. A-19, A-20).

Abatement of pollution in this area would be expected to be followed by a decrease in the relative importance of Limnodrilus spp., expansion of the areas occupied by P. multisetosus and Aulodrilus, increase in relative importance of these and some other taxa currently less numerous (Table A-4), and invasion by other species not currently found in the area. On the other hand, worsening of conditions would eliminate P. multisetosus and Aulodrilus completely and result in a fauna consisting solely of L. hoffmeisteri and L. cervix-claparedeianus. Areas near the Indiana Harbor outlet would probably become devoid of macrobenthos. It

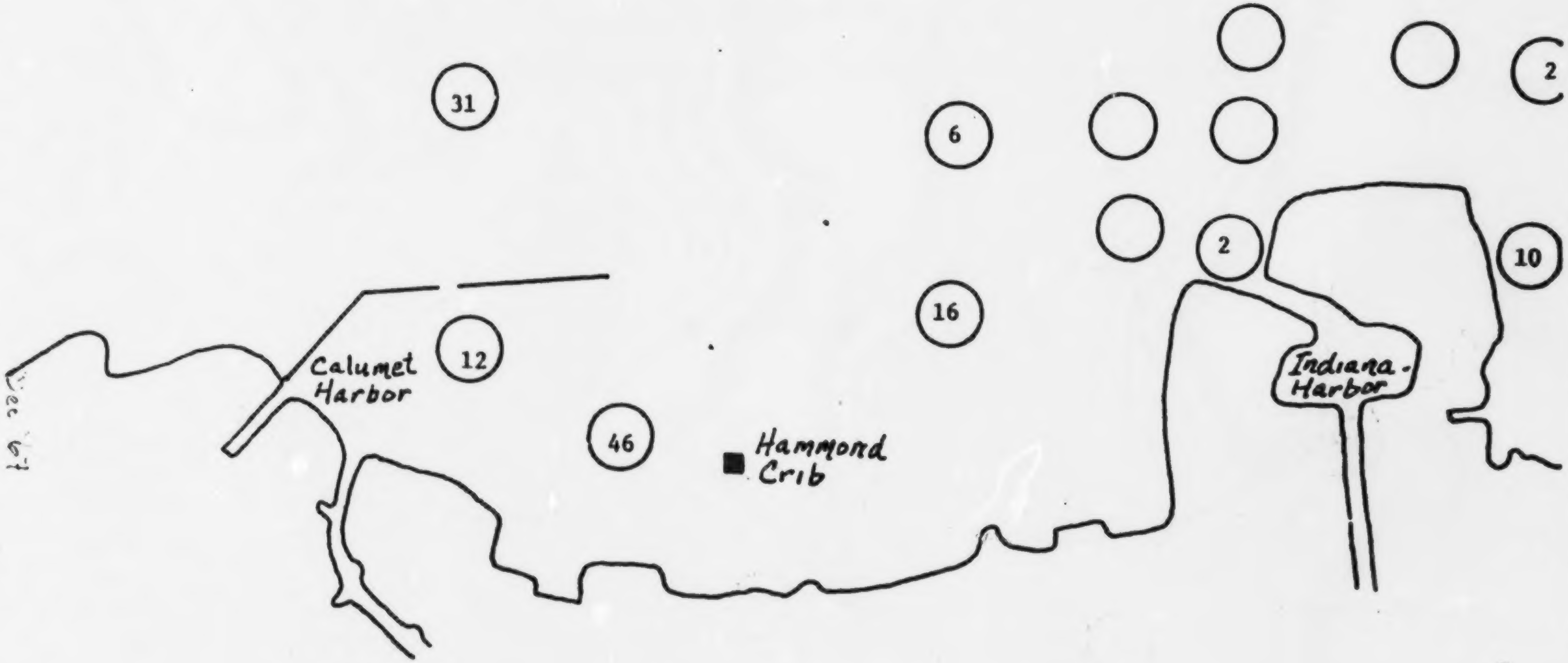
31
6
2
12
16
2
10
46
Calumet Harbor
Hammond Crib
Indiana-Harbor
Dec '67

Figure A-17. Relative abundance of Peloscolex multisetosus (percentage of all oligochaetes) at stations of December 1967.

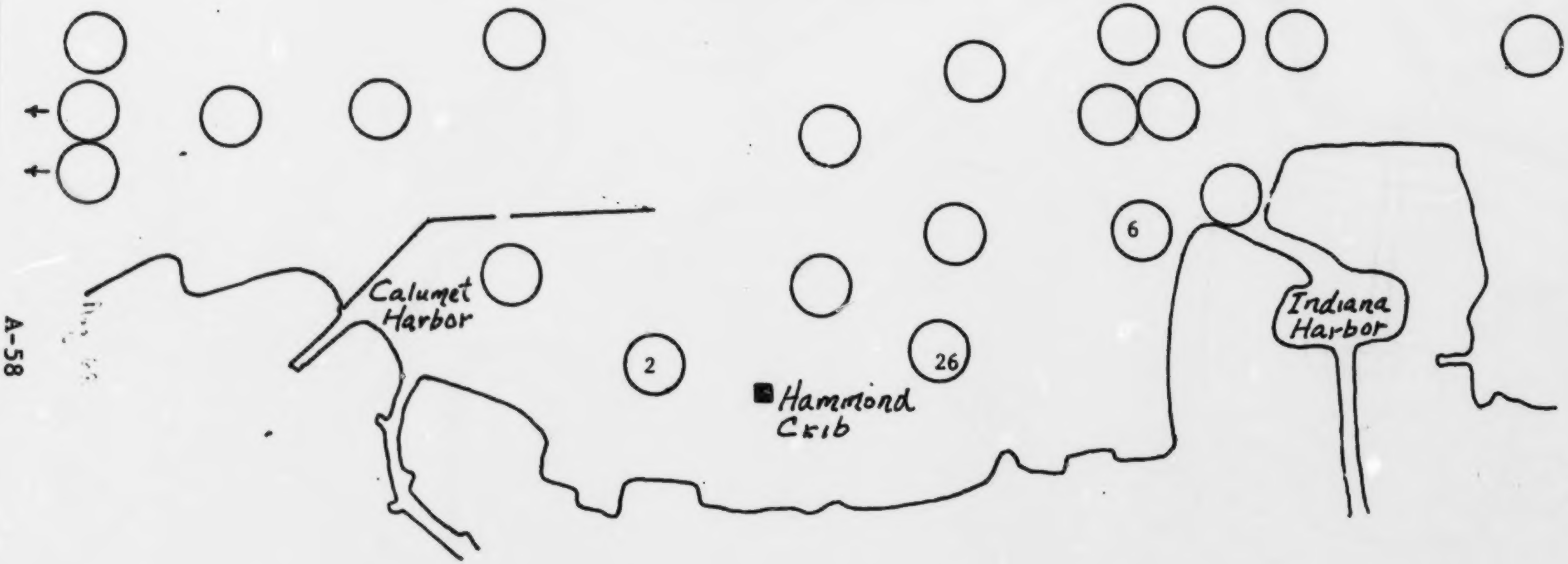
Calumet Harbor
2
Hammond Crib
26
6
Indiana Harbor

Figure A-18. Relative abundance of Peloscolex multisetosus (percentage of all oligochaetes) at stations of August 1968.

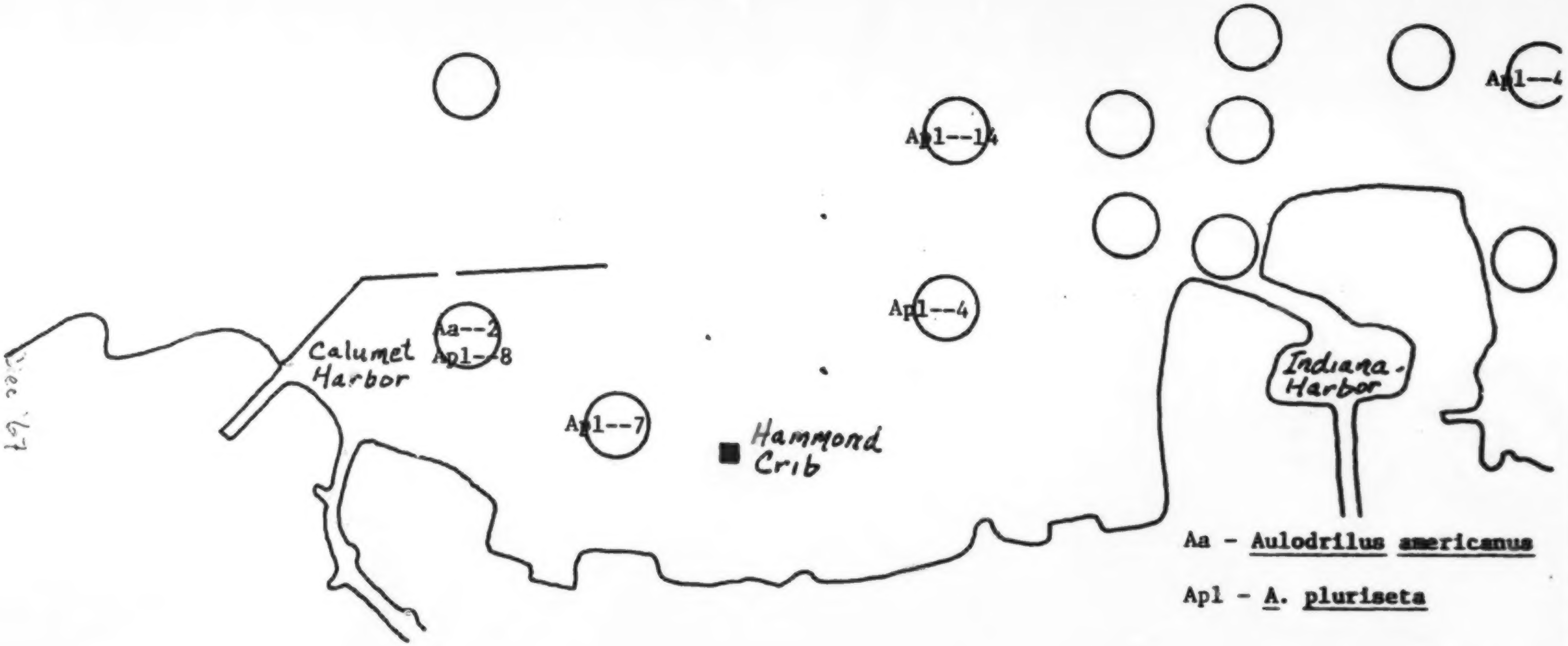
Apl--4
Apl--14
Aa--2
Apl--8
Calumet Harbor
Apl--7
Hammond Crib
Apl--4
Indiana-Harbor
Aa - Aulodrilus americanus
Apl - A. pluriseta
Dec '67

Figure A-19. Relative abundance of worms of the genus Aulodrilus (percentage of all oligochaetes) at stations of December 1967.

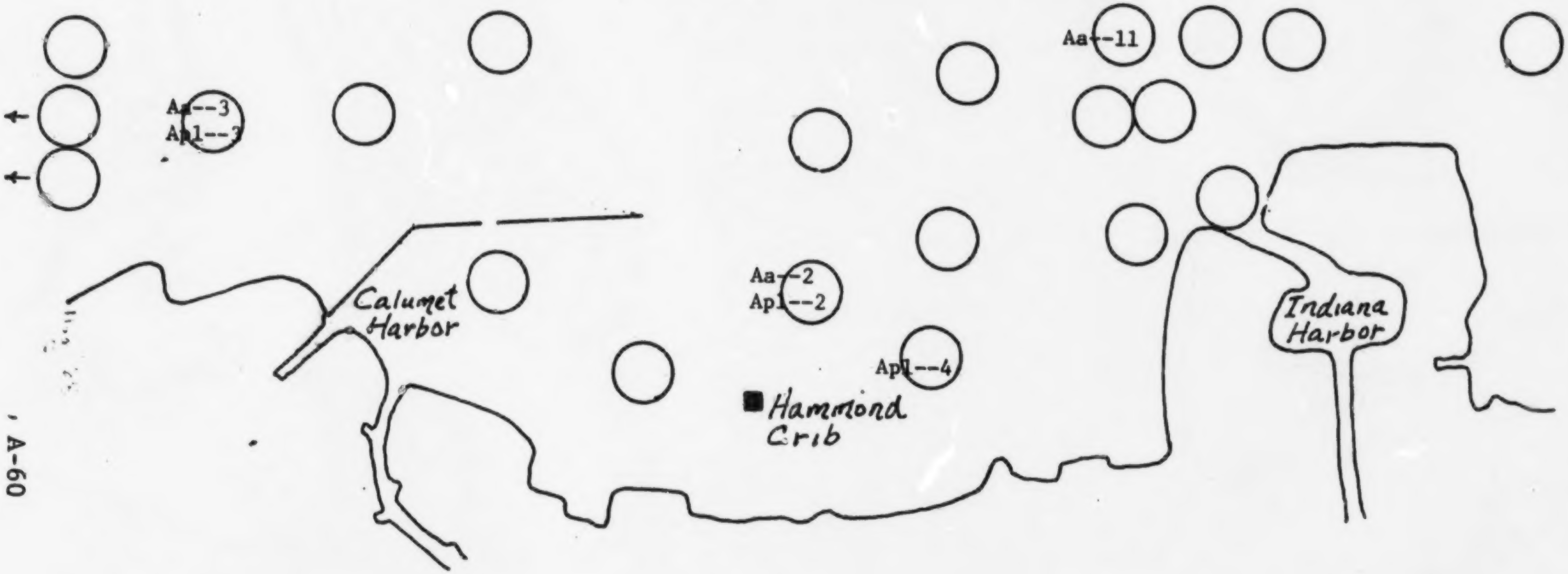
Aa--3
Apl--3
Aa--11
Aa--2
Apl--2
Apl--4
Calumet Harbor
Hammond Crib
Indiana Harbor

Figure A-20. Relative abundance of worms of the genus Aulodrilus (percentage of all oligochaetes) at stations of August 1968.

can thus be seen that this study of the composition of the worm fauna can serve as a valuable baseline from which to measure future changes in environmental quality in this area. Analysis of the worm fauna at the species level becomes particularly necessary when, with increasing levels of pollution, other invertebrates are eliminated while worms become an increasingly abundant part of the fauna (cf. Carr and Hiltunen 1965, Howmiller and Beeton 1971).

Effects of Benthos on Sediment-Water Exchange

A number of studies have shown that burrowing benthic invertebrates can have important effects upon the structure of sediments and upon exchange of materials between sediments and water. These effects may be caused by mechanical overturn of sediments, chemical transformation of sediment within the gut of the animal, or by irrigation of burrows with consequent changes in the stratification of redox potential.

This area has been so little studied that we have no good estimate of the importance of these processes under various natural conditions. However, the studies which have been published give an indication that the subject should not be ignored in programs concerned with pollution abatement or eutrophication control. For example, concentrations of pollutants or plant nutrients may not change in direct response to changes in inputs if the new conditions alter the rate at which invertebrates cause release of the substance(s) from the sediments.

Various authors have attempted to estimate the rate at which tubificid oligochaetes overturn sediments. Results have been variable but indicate that it may range to 6-12 $kg/m^2/yr$ (Lundbeck 1926). Clearly, mixing of this magnitude could have substantial effects on chemical processes.

Tubificids (Zvetlova 1972) and chironomid larvae (Rossolimo 1939, Edwards 1958) have been shown to increase the rate of oxygen consumption by sediments.

Howmiller (unpublished) conducted an experiment in which Limnodrilus hoffmeisteri, at densities equivalent to 10,000 and 50,000 /m^2, were placed in Milwaukee Harbor mud and covered with filtered Lake Michigan water. Three sets were run; at high and low oxygen concentrations and under anaerobic conditions. In all cases the water increased more in phosphate concentration than it did in comparable controls lacking worms.

Jernelov (1970) showed that tubificids, and also the clam Anodonta, cause an increase in the depth from which mercury is released to the overlying water. Yealy (1971) studied uptake of methyl-mercury and effects on release to the water by three common Lake Michigan invertebrates; Stylodrilus heringianus, Pontoporeia affinis, and a sphaeriid clam. Results suggested that the organisms enhanced the release of mercury and Yealy believed that Stylodrilus played an especially important role in this respect. It had the highest uptake of methyl-mercury of the three species studied.

Review of this subject has been cursory but an exhaustive treatment would bring us to the same conclusion, viz: research has been insufficient to provide generalizations but the subject seems an important one for consideration of nutrient and pollutant pathways. This is especially true in many parts of the Great Lakes, such as the Calumet area, where the sediments contain high concentrations of nutrients and pollutants (Fig. A-10).

Recommendations for Applied Research on the Benthos of the Calumet Area

Species Distributional Patterns

An earlier section was devoted to discussion of the use of species distributional patterns, and the relative abundance of species with indicator value, in documenting the state of the environment. Another section reviewed existing knowledge of this sort for the Calumet area. The major short-coming of this study was that it covered only a restricted area; an area obviously grossly polluted with inputs from Calumet and Indiana Harbors.

There seems little point in duplicating this study in the near future as we have little reason to believe that environmental conditions in the area have undergone substantial change. However, a survey is needed which will extend the area investigated; to determine the areal extend of degradation of the benthic environment in the Calumet area. The only study which has attempted to provide this information (FWPCA 1968a) is woefully inadequate because it employed a sampling device known to be very ineffective, because organisms were not identified to species, and (while station locations are not given in the report) it appears to have taken few samples in the Calumet area.

Following is a proposal for a sampling plan which would provide a far better picture of the benthic communities in the Calumet area. Samples should be taken in triplicate on a (60°) diagonal grid (Fig. A-21) a pattern which gives the most even coverage of the area and allows calculation of indices of similarity between benthic assemblages over uniform distance. The usefulness of an index of similarity between assemblages at adjacent stations is in providing a numerical value representing quantitative and qualitative change in the benthos and thus change in environmental conditions. The value used should take into consideration both the number of species in common and differences in equitability (evenness of distribution of individuals among species). A measure of "overlap" based on information theory may be suitable for the purpose (Horn 1966).

Needless to say, this will require species identification of all organisms, and I hasten to recommend that quantitative species lists, as well as exact locations, be presented in any report on the survey. Altogether too often it is impossible to reproduce an earlier study, or to analyze the data in light of new concepts, because the authors give only their reduced data and we really have no idea of how much of what was found where.

The Ponar grab is recommended as the sampler of choice for the Calumet area. It is more effective than the Petersen on hard or soft substrates (Powers and Robertson 1967), and while less effective than the Ekman grab on mud (Howmiller 1972) it is at least better than the Petersen (Powers and Robertson 1967). Since the Ponar is used for most benthic investigations by the Great Lakes Research Division (Univ. Michigan) and the Center for Great Lakes Studies (Univ. Wisconsin-Milwaukee), the major research groups on the lake, its use in the Calumet area will facilitate comparison of data with a maximum number of other studies. Two samplers which may initially have great appeal, because they will obtain a sample from most any kind of substrate, are the Shipek and orange-peel. These should not be used as they have been shown to be quantitatively ineffective for biological samples (Sly 1969, Flannagan 1970)

Benthic samples should be screened immediately using a U.S. Std. No. 30 Mesh (0.565 mm) as this is the mesh most commonly employed in Great Lakes Studies (Mozley and Howmiller 1973). Residue from the screen should be preserved immediately with buffered 10% formalin (4% formaldehyde). Low power magnification should be used in separating organisms from the screen residue and the most recent monographs used in their identification.

It is perhaps worth pointing out that safe and efficient fieldwork requires a seaworthy vessel fitted with a sonic depth finder and navigational radar. The vessel should have ample deck space, a (powered) hydrographic winch, and water under pressure piped to the working deck. The R/V Mysis (Great Lakes Research Division) and R/V Neeskay (Center for Great Lakes Studies) are examples of suitable vessels for benthic sampling.

A tentative sampling plan, shown in Figure A-21 involves 15 stations on a two mile diagonal grid. Under favorable weather conditions, and with a suitable vessel, sampling could be accomplished in a day by experienced personel.

The proposed plan is, of course, tentative. Preliminary sampling, or analysis of water quality data, may indicate that some modification would be desirable. For example, one might wish to expand the area of investigation, especially in the direction of the usual path of water originating in the Calumet-Indiana Harbor area.

Effects of Benthos on Chemical Parameters

Attempts at modeling expected changes in water quality should not ignore the possible importance of benthic organisms in facilitating chemical transport across the sediment-water interface. In the Calumet area new effluent standards may result in lower concentrations of toxic

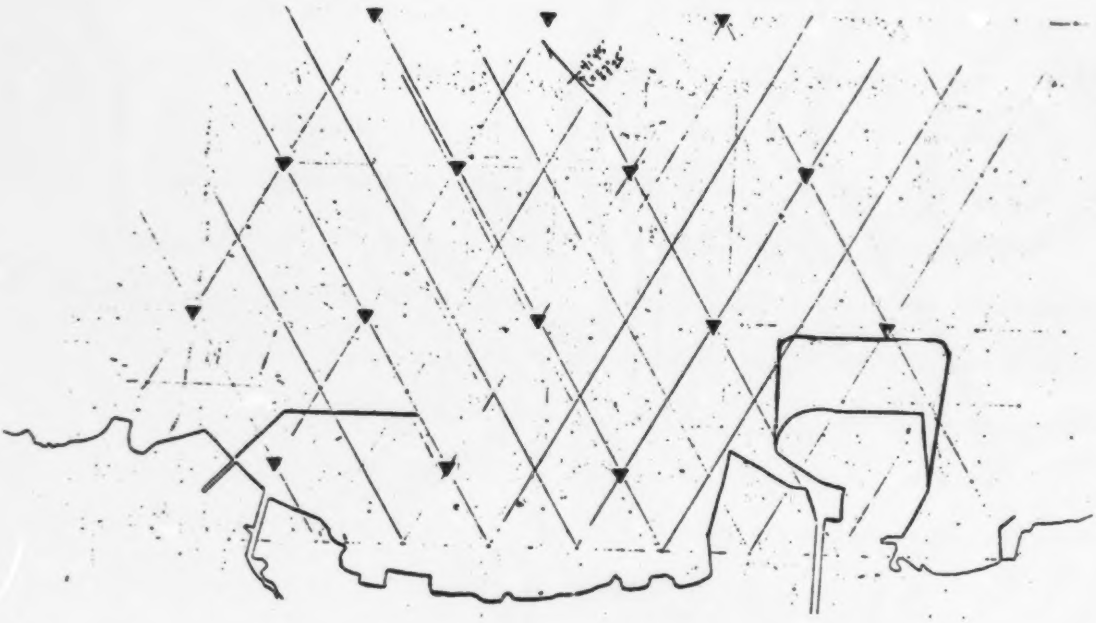

Figure A-21. The above map was drawn from Lake Survey Chart No. 751.

▼ - Proposed sampling stations

Compass Headings for possible runs between stations
313 NW* and 133 SE* (along lettered transect line)
213 SW** and 43 NE** (along numbered line)
13 NNE*, 193 SSW*, 73 ENE* and 253 WSW* (diagonal)

* On these runs distances between adjacent stations are exactly 2.0 mile
** On these runs distances between stations are ca 3.46 mile

substances and higher concentrations of oxygen in and near the harbor areas. This could conceivably allow a great increase in benthic populations since the sediments, in many places, have abundant organic matter for them to exploit. Greatly increased populations of burrowing benthic invertebrates could cause a large difference in the rate at which certain substances are released from, or bound to, the sediments. This possibility must be considered in attempts to predict future water quality.

This situation demands research to estimate current rates of sediment-water exchange of important materials (oxygen, phosphorus, nitrogen compounds, metals). It must also include predictions of effects of anticipated water quality changes upon the abundance of benthic invertebrates and upon their effect on sediment-water interactions. This is a very complex problem for which basic science has not yet provided the groundwork. However, the current fiscal situation in basic science seems to suggest that we have to wait a long time for answers to certain questions. In such a case basic research must become "applied" in areas where real or potential problems exist.

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APPENDIX B

THE ECOLOGY OF LAKE MICHIGAN ZOOPLANKTON - A Review with Special Emphasis on the Calumet Area

by

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I. INTRODUCTION

The zooplankton community of Lake Michigan consists primarily of a diverse assemblage of Rotifera and microcrustaceans (Cladocera and Copepoda). These organisms are quantitatively abundant and significant in food chain dynamics and energy flow characteristics of the Lake Michigan ecosystem. They spend most of their life history in the water column.

A few other organisms are predominately bottom-dwellers but at times can be collected in the plankton. Some non-photosynthetic Protozoa (e.g., Difflugia) are normally benthic in habit but occasionally are found in large numbers in the plankton. The opposum shrimp, Mysis relicta, and the deepwater amphipod, Pontoporeia affinis, typically are in lake bottom sediments during the day and migrate into the water column at night. Many aquatic insects spend their larval stages in the benthos and become planktonic only for a brief portion of their life cycle when they move towards the lake surface in preparation for emergence into the terrestrial environment as adults. Many larval fishes spend a brief time in the plankton before assuming predominately bottom-dwelling habits. In addition, a variety of small invertebrates (Ostracoda, Hydracarina, Nematoda, Annelida, and some Cladocera and Copepoda) are characteristically found on bottom or among rooted plants and at times are temporarily swept into the plankton in turbulent near-shore waters.

Since the euplanktonic Rotifera, Cladocera, and Copepoda comprise most of the total biomass of Lake Michigan zooplankton, this review will be concerned only with these organisms. The biology and ecology of rotifers and micro-crustaceans in Lake Michigan are poorly understood even though over 60 scientific papers have appeared on the subject since the late 19th century (Gannon 1969). Most papers are descriptive, concentrating heavily upon taxonomy and distribution in space and time. Few papers have been concerned specifically with the Calumet area of southern Lake Michigan, and fewer still have dealt with zooplankters in relation to water quality problems in that region.

The earliest studies on Lake Michigan zooplankton were strictly taxonomic. They were prompted by curiosity about the kinds of organisms found in city water supplies. Later, concern about water pollution from municipal sewage and industrial wastes initiated further studies. However, zooplankton received little attention since most of the emphasis was placed upon chemical parameters, coliform bacteria, and phytoplankton. Renewed interest in Lake Michigan zooplankton has occurred during the past decade due to concern about rapidly fluctuating fish stocks and the recent predominance and abundance of planktivorous fish, such as alewife, Alosa pseudoharengus, and smelt, Osmerus mordax. Additional

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impetus for zooplankton research has been prompted by concern about thermal and radioactive pollution effects on Lake Michigan biota by waste water discharge from nuclear electric power generating stations.

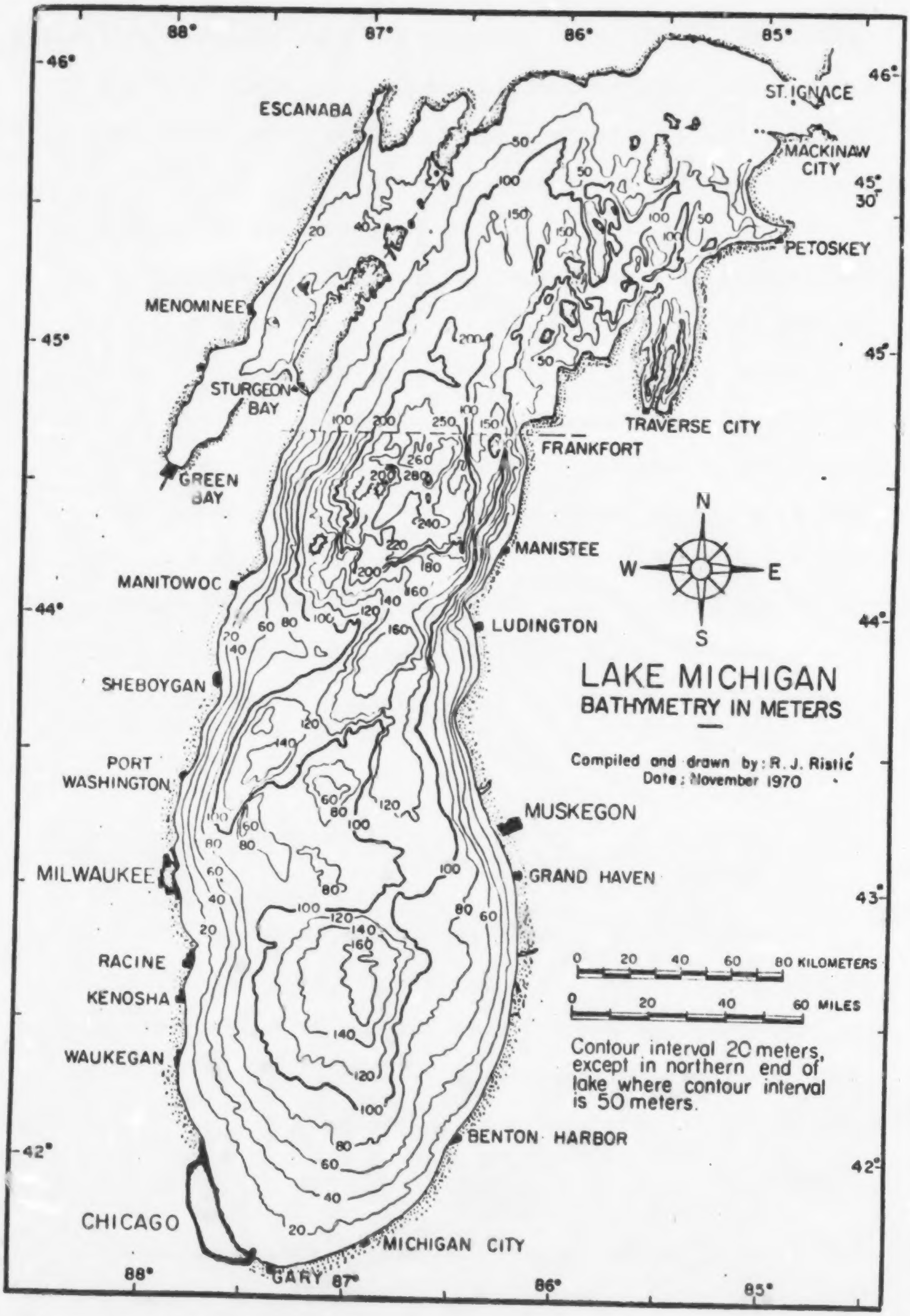
This report is a review of pertinent literature on the ecology of zooplankton with particular emphasis on the Calumet area of southern Lake Michigan (Figure B-1). The discussion must not be limited precisely to the Calumet area alone. Zooplankters by no means are confined to artificial boundaries created by man. The limnology of Lake Michigan is characterized by complex and massive hydrodynamics that undoubtedly sweep zooplankters in and out of the Calumet region. Zooplankton research which has been conducted elsewhere in the Lake Michigan basin but containing data pertinent to the Calumet area will be discussed.

II. A BRIEF SYNOPSIS OF ZOOPLANKTON INVESTIGATIONS IN THE LAKE MICHIGAN BASIN

This section includes a brief discussion of papers dealing with zooplankton ecology throughout Lake Michigan. The intent is to identify data sources of information on various aspects of zooplankton ecology pertinent to future work on zooplankton in the Calumet area.

TAXONOMY

Early investigations on Lake Michigan zooplankton were strictly taxonomic. Birge (1882) briefly listed 9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GREEN BAY
MANISTEE
MANITOWOC
LUDINGTON
SHEBOYGAN
PORT WASHINGTON
MUSKEGON
MILWAUKEE
GRAND HAVEN
RACINE
KENOSHA
WAUKEGAN
BENTON HARBOR
CHICAGO
MICHIGAN CITY
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LAKE MICHIGAN
BATHYMETRY IN METERS
Compiled and drawn by: R. J. Ristić
Date: November 1970
0 20 40 60 80 KILOMETERS
0 20 40 60 MILES
Contour interval 20 meters, except in northern end of lake where contour interval is 50 meters.
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Figure B-1. Morphometric map of Lake Michigan. The focus of this report is on the Calumet area of extreme southwestern Lake Michigan extending from the 68th Street Chicago water intake crib to Burns Harbor near Gary, Indiana.

species of Cladocera found in the City of Chicago water supply. Forbes (1882) provided descriptions of some zooplankton Crustacea collected near Chicago, Illinois; off Racine, Wisconsin; and in Grand Traverse Bay. Marsh (1895), Jennings (1896), and Kofoid (1896) gave taxonomic accounts of Copepoda, Rotifera, and Protozoa, respectively, collected in a biological survey of the Grand Traverse Bay region (Ward 1895;1896). Schact (1897; 1898) and Marsh (1909; 1929) used specimens from Lake Michigan in taxonomic treatments of North American Copepoda. Ahlstrom (1936), in the first offshore investigation of plankton in Lake Michigan, examined phytoplankton, Protozoa, and Rotifera from net tows in the southern portion of Lake Michigan during 1930 and 1931. None of his stations included the Calumet area, but this work represents the most detailed account available on rotifer species composition in the offshore waters of Lake Michigan. Many species encountered in Ahlstrom's study undoubtedly occur at times in the Calumet region. The most recent taxonomic study using specimens from Lake Michigan was by Deevey and Deevey (1971) who revised a portion of the cladoceran family, Bosminidae.

PLANKTON BIOMASS

Several studies have examined total plankton biomass, including zooplankton, at municipal water intakes at Milwaukee, Wisconsin (Damann 1966) and at Chicago, Illinois (Baylis and Gerstein 1929; Lackey 1944; Damann 1945, 1960;

Gamet and Rademacher 1960; Gerstein 1965; Vaughn 1969; Vaughn and Reed 1972). Total counts of plankton have been routinely monitored where phytoplankton, mainly diatoms, have caused clogging of filters and taste and odor problems in city water supplies. Since phytoplankton and zooplankton numbers were normally combined, and since zooplankters are usually less than 0.1 percent of net phytoplankton counts (Damann 1945), these data contain little information concerning zooplankton. Identifications of zooplankton, if attempted at all, were usually confined to the most abundant genera. Total plankton count data have been useful only in applied problems related to drinking water supplies and in detecting a significant increase in phytoplankton abundance in southern Lake Michigan during the past 50 years (see Howmiller 1973, p. A-1).

Further data from water intake stations in Lake Michigan were obtained by Williams (1962; 1966) as part of the National Water Quality Network program conducted by the U.S. Public Health Service in 1957 through 1962. Two Lake Michigan stations (Gary, Indiana and Milwaukee, Wisconsin) were among 128 stations established in the Great Lakes and on major rivers across the United States. Emphasis in this investigation was on phytoplankton but limited quantitative data were obtained on rotifers, cladocerans, and copepods. In comparison with stations elsewhere, Lake Michigan exhibited a particularly rich rotifer fauna.

Zooplankton biomass measurements, as dry weight and particulate organic matter, were made by Robertson and Powers (1965;1967) and Powers et al. (1967) in Lake Michigan during 1964-66 and by Ayers and Huang (1967) during 1964 in Milwaukee Harbor. These data may be useful for comparative purposes when similar tests are run in future years, but presently contribute little to our knowledge of Lake Michigan zooplankton ecology.

SEASONAL AND VERTICAL DISTRIBUTION

Eddy (1927) obtained the first data on seasonal distribution of zooplankton in Lake Michigan. He examined plankton from near-shore surface tows taken in the extreme southern end of the lake during 1887-88 and 1926-27. Most of these data were treated qualitatively although some semi-quantitative results were presented for a few dates in 1926-27. Wells (1960) conducted the first truly quantitative study at offshore stations 13 km (8 mi) west of Grand Haven, Michigan in 1954 and 4.8 km (3 mi) west of Frankfort, Michigan in 1955 using a Clarke-Bumpus sampler. Detailed data on seasonal and vertical distribution of zooplankton Crustacea were obtained on 10 dates from June through November. This work still stands as the most thorough investigation of zooplankton ecology ever conducted in the Lake Michigan basin.

Wells (1970) resampled his 1954 station off Grand Haven, Michigan in 1966 and 1968 at the same time of the year using identical methods. He noted dramatic changes in zooplankton size and species composition between 1954 (pre-alewife abundance) and 1966 (maximum alewife abundance). All species larger than 1.0 mm, except *Diaptomus oregonensis*, sharply declined to one-fourth or less of their former abundance while all smaller species, except *Diaptomus minutus*, increased 1.2 to 72 times over their 1954 standing crop (Table 1). Several species (*Eubosmina coregoni*, *Daphnia longiremis*, *Ceriodaphnia quadrangula*, and *Eurytemora affinis*) appeared in the community in 1966 that were not reported in 1954. Size-selective predation by alewife was strongly suspected as the causative factor. In 1968, following the massive alewife die-off of 1967, there was some evidence that the zooplankton community was shifting back to composition similar to pre-alewife abundance. Many of the larger species increased in abundance from 1966 to 1968, although *Daphnia galeata-mendotae* and *Mesocyclops edax* still remained exceedingly rare (Table B-1).

Gannon (1972a) contributed information on abundance and distribution of zooplankton Crustacea in Lake Michigan off Milwaukee, Wisconsin in 1968-70. Seasonal distribution was studied at two stations, an inshore station in Milwaukee Harbor and an offshore station 18 km (10 mi) east of Milwaukee. This investigation presented the only detailed data available on Lake Michigan zooplankton Crustacea during the winter months. A parallel study was conducted by Stemberger (1973) on the Rotifera of the Milwaukee Harbor

Table B-1. **Abundance of zooplankton Crustacea in 1966 and 1968 relative to that in 1954. Calculated from Wells' (1970) data for mid-July and early August in Lake Michigan off Grand Haven, Michigan.**

Species	Mean Length (mm)	Abundances relative to 1.00 in 1954	
		1966	1968
Cladocera			
Leptodora kindtii	5 ±	0.17	0.65
Daphnia galeata-mendotae	1.1	<0.01	< 0.01
Daphnia retrocurva	1.1	0.03	1.18
Diaphanosoma leuchtenbergianum	0.9	0	0
Polyphemus pediculus	0.7	72.08	144.09
Bosmina longirostris	0.5	4.63	1.94
Copepoda			
Senecella calanoides	2.9	0.25	0.75
Limnocalanus macrurus	2.5	0.23	2.11
Epischura lacustris	1.7	0.09	0.56
Diaptomus sicilis	1.3	0.25	0.58
Mesocyclops edax	1.2	0	< 0.01
Diaptomus oregonensis	1.1	1.22	0.90
Cyclops bicuspidatus thomasi	0.9	2.85	2.17
Diaptomus ashlandi	0.8	1.16	0.21
Diaptomus minutus	0.8	0.72	4.93

region during 1972. This study presents the only comprehensive analysis available on rotifer species composition and abundance for the inshore waters of Lake Michigan. Since the investigations of Gannon (1972a) and Stemberger (1973) were partially conducted in the enriched waters of Milwaukee Harbor and represent the most complete studies to date on zooplankton species composition and distribution in Lake Michigan, they should be of interest to future workers on zooplankton in the Calumet area of Lake Michigan.

Based upon the studies of Gannon (1972a) and Stemberger (1973), Gannon (1972b) discussed the relative effects of eutrophication and fish predation on recent changes in zooplankton species composition in Lake Michigan. Both eutrophication and size-selective predation can cause a decrease in the size composition of zooplankton and such changes often entail shifts in species composition. Since eutrophication and fish predation often result in similar changes in zooplankton size and species composition, it is often difficult to distinguish the effects of these two factors on the zooplankton community. However, it was noted that oligotrophic offshore waters of Lake Michigan contained high numbers of calanoid copepods relative to cladocerans and rotifers and the opposite was true for the more eutrophic inshore waters. It was suggested that the relative proportions of calanoid copepods to cladocerans and rotifers may be useful in indicating the state of eutrophication of Great Lakes waters (Gannon 1972b).

A few additional studies have presented limited data on seasonal distribution and abundance of Lake Michigan zooplankton. Seasonal distribution of diaptomid copepods in western Lake Michigan during spring through fall, 1964 was reported by Robertson (1966). Manny and Hall (1969), in an attempt to measure community metabolism by the diurnal oxygen curve method, obtained limited data on zooplankton abundance in the surface waters near Grand Haven, Michigan in July, 1968.

Schelske and Roth (1973) obtained limited zooplankton data from 6 stations in northern Lake Michigan on 7 July 1970. Information on zooplankton (mostly Crustacea) biomass by volume determinations and generic composition was procured. These data offer little information on Lake Michigan zooplankton alone. However, they are useful in comparing zooplankton Crustacea community structure and abundance in Lake Michigan with other Great Lakes since identical methods were employed on Lakes Superior, Huron, and Erie.

In addition to the data of Wells (1960) on vertical migration of zooplankton Crustacea in Lake Michigan, McNaught (1966) and McNaught and Hasler (1966) obtained more detailed information from a station off Saugatuck, Michigan during summer, 1964 and another off Ludington, Michigan in spring, 1965. Correlations were made between vertical migration patterns of several species, visual sensitivity of those species to spectral composition of light, and changes in light intensity. Lane and McNaught (1970) reexamined data from August, 1964 using mathematical analyses of niche specificity. Habitat selection through vertical migration was considered the most significant mechanism for separating niches among "omnivorous" and "herbivorous" zooplankters.

HORIZONTAL DISTRIBUTION

Several investigations have examined horizontal distribution of zooplankton in the offshore waters of Lake Michigan. The Hardy continuous plankton recorder has been utilized in two investigations in the offshore waters of the lake. Robertson (1968) presented limited data for Lake Michigan in 1965 and 1966 while exploring possibilities of adapting the Hardy recorder for use in the Great Lakes. Swain, Olson, and Odlaug (1968;1970) towed a continuous plankton recorder at a depth of 10 m along the longitudinal axis of the lake during July and August, 1966 and July and October, 1967. Since only one depth was sampled at all hours of the day and night, these data are difficult to interpret due to unmeasured effects of vertical migration on the samples obtained. In general, Daphnia and Bosmina were more abundant at the southern end of the lake than elsewhere. Cyclops was most abundant nearer the shorelines.

Interest in the dispersal of pollutants in the nearshore waters of Lake Michigan have spurred a number of investigators to pursue studies on horizontal distribution of zooplankton near harbors and other point sources of potential pollutants. Several investigations have been conducted in the vicinity of Milwaukee Harbor and a considerable number of studies are currently underway in the vicinity of nuclear electric power generating stations mostly in the southern portion of the lake.

In the Milwaukee Harbor region, Torke (1971) studied the distribution and abundance of Cladocera near the Milwaukee Harbor in August and September, 1969. In general, no significant differences in inshore-offshore species composition or abundance were detected. Only the higher abundance of *Daphnia retrocurva* offshore (8-16 km) than inshore (0.4-3.2 km) was statistically significant. Gannon (1972a) investigated horizontal distribution of zooplankton Crustacea by obtaining a series of samples from the cooling water intake of a Chesapeake and Ohio railroad ferry as it steamed across the lake along a northeast course from Milwaukee, Wisconsin to Ludington, Michigan. The sampling program was conducted overnight on six dates from March, 1969 through January, 1970. Horizontal distribution of zooplankton was notably uniform during spring, fall, and winter. However, contrary to the results of Torke (1971), obvious inshore and offshore differences in abundance were observed during summer. Certain species (such as *Bosmina longirostris* and

Cyclops bicuspidatus thomasi) were dramatically more abundant in the near-shore waters (0-15 km) off Milwaukee in comparison with stations farther offshore. Higher numbers off Milwaukee reflect a response by the zooplankters to nutrient enrichment of the near-shore waters by the discharge of municipal sewage, industrial wastes, and storm water run-off from the Milwaukee River watershed. Inshore and offshore differences were evident but less distinct off the small town of Ludington, Michigan.

Even more dramatic results of inshore and offshore differences were noted in Stemberger's (1973) study of rotifers in the Milwaukee Harbor region. Certain species, most likely of lotic origin, were found only in the harbor region. Lentic forms characteristic of the Lake Michigan biota decreased dramatically in abundance at stations further offshore. Rotifers near the harbor appear to be responding to higher nutrient conditions with faster growth rates enabling a large biomass to be accrued.

Our knowledge of zooplankton ecology in the coastal zone of Lake Michigan has been augmented considerably by investigations on the impact of heated water discharges from electric generating stations on Lake Michigan biota. Much of this research is currently underway and many reports are unavailable for review at this date. Investigations on zooplankton have formed an integral part of many of these studies. Most notable are the investigations of Roth and Stewart (in press; also in Ayers and Seibel 1973) in the vicinity of the Donald C. Cook Nuclear Power Plant near St. Joseph, Michigan. Abundance and distribution of zooplankton Crustacea were investigated at three stations ranging from inshore (1.2 km from shore) to offshore (11.2 km from shore) from April through November, 1972. A distinct inshore fauna consisting predominately of Cladocera was noted. Persistence of a distinct inshore fauna was attributed to one or a combination of the following factors: thermal stratification, high near-shore primary productivity, or fish predation. Industrial Bio-test, Inc. (1972) has been investigating thermal effects at two power plants in southwestern Lake Michigan since spring, 1971. Zooplankton Crustacea species composition and abundance have been investigated quantitatively in the coastal waters at a functional fossil fuel plant near Waukegan, Illinois and a nuclear plant currently under construction near Zion, Illinois. Investigations on entrainment and condenser passage by zooplankton have also been conducted at the Waukegan plant. Mortality was low (average of 6 percent) with mechanical abrasion indicated as a more important cause of death than temperature stress. A more limited study was also conducted by Industrial Bio-test Laboratories, Inc. (1971) at the Bailey generating station near Gary, Indiana prior to conversion of the plant from fossil to nuclear fuel. Distribution of zooplankton Crustacea was determined inside and outside of the thermal plume area during October, 1970. Cladocera (mainly Daphnia and Bosmina) were significantly more abundant in the plume while copepods (mostly Diaptomus) were more prevalent outside the plume.

ZOOPLANKTON AS FOOD FOR FISH

Interest in the adequacy of the plankton food supply for commercially valuable fish in Lake Michigan prompted several studies on zooplankton. Forbes (1882) wrote:

> "One cannot go far in the study of organic life which prevails in a stream or lake, without being made aware of the important part played therein by the neglected but interesting group of the smaller crustaceans. They occupy a central position not only in the classification of aquatic animals, but also in the complicated network of physiological relations by which the living forms of a body of water are held together as an organized society. Feeding, themselves, upon the lowest and smallest of plants and animals, they furnish food in turn to a great variety of the higher animals, and even to some plants.
>
> "The fisherman who toils at his nets, the sportsman in pursuit of health and recreation, rarely reflect, even if they know, that their amusements and their labors depend strictly upon these humble creatures, of whose very existence, indeed, many of them are unaware; and yet there is ample evidence that, with few and unimportant exceptions, all young fishes, of our fresh waters at least, live for a time almost wholly upon entomostraca."

Forbes (1883; 1888) ran a series of laboratory experiments on the first food of larval whitefish, Coregonus clupeaformis, using plankton from southern Lake Michigan. Cyclops and Diaptomus were the most important food surces following absorbance of the yolk sac. Wells and Beeton (1963) examined stomach contents of 1,469 bloaters, *Coregonus hoyi*, collected from various locations in Lake Michigan during 1954 through 1961. Bloaters under 18 cm (7 in) long fed heavily upon zooplankton Crustacea. The most frequent species in stomachs were *Cyclops bicuspidatus thomasi*, *Diaptomus* spp., and *Daphnia galeata-mendotae*. Fish larger than 18 cm fed predominately on *Pontoporeia* and *Mysis*.

The population explosion of alewife, *Alosa pseudoharengus*, during the last decade prompted several studies on the food habits of this species. Norden (1968) examined the food of larval alewife (0.5-6.7 cm) in Milwaukee Harbor during August, 1966 and August through October, 1967. Positive selection for both cladocerans and copepods was generally observed. *Cyclops* spp. and *Bosmina* spp. were most prevalent in larval alewife stomachs. Morsell and Norden (1968) examined food habits of juvenile and adult alewife in Lake Michigan from May, 1966 through July, 1967. Cladocera and Copepoda comprised most of the alewife diet. *Limnocalanus macrurus* was most common in profundal zone collections while *Cyclops bicuspidatus* and *Diaptomus* spp. were most prevalent in littoral collections. *Bosmina longirostris* and *Diaptomus* spp. were prominent in stomachs of alewife collected in summer.

A series of studies most pertinent to the Calumet area have been conducted on interspecies relationships of fish in the Indiana waters of Lake Michigan. The investigations were conducted by graduate students from

Ball State University under the leadership of T. S. McComish. Three of the investigations have involved zooplankton. Johnson (1972) conducted quantitative studies on zooplankton species composition and abundance during June through October 1970. Two parallel studies examined food habits of the alewife in the same region (Rhodes 1971; Webb 1973). These investigations represent the most thorough studies on zooplankton ecology in the Calumet area of Lake Michigan and will be discussed in detail in the next section.

ZOOPLANKTON IN GREEN BAY

All previously mentioned studies have been conducted in the main portion of the Lake Michigan Basin. Although Green Bay is geographically distant and morphologically distinct from the Calumet area of Lake Michigan, the two regions are similar in that they both receive high volume waste water discharges from municipal and industrial sources. Consequently, it may be of interest to briefly mention the few studies that have been conducted in the Green Bay region.

Balch, et al. (1956) collected zooplankton samples in lower Green Bay during February, 1955 and in the Fox River during April and July, 1955 using a plankton trap of unknown dimensions. Data were expressed only as numbers of Cladocera, Copepoda, and nauplii per unit volume.

These data indicate that the Fox River supports high numbers (8,000-400,000 per m^3) of zooplankton Crustacea during summer. It was estimated from dry weight measurements that 1.24×10^5 kg (136.4 tons) of plankton was flowing from Lake Winnebago and entering the lower Fox River. Judging by plankton densities throughout the river, a considerable biomass of plankton is suspected to enter Green Bay by way of the river.

The open waters throughout Green Bay were sampled with vertical tow nets in 1969-70 during all seasons by Gannon (1972a). The zooplankton Crustacea of southern Green Bay differs substantially from that of the northern portion of the Bay and Lake Michigan proper. Due to the shallow nature of southern Green Bay, the incidence of littoral and benthic micro-crustaceans in the plankton was higher in this region than elsewhere in the Lake Michigan basin. The southern portion of the Bay is strongly influenced by the inflow of the Fox River. Water from the Fox River retains its identity from 35 to 50 km north of the river mouth along the eastern shore of the Bay. This zone of Fox River water in southrn Green Bay exhibits faunal characteristics most dissimilar to Lake Michigan. Standing crop of zooplankton Crustacea was generally higher in the zone of Fox River water than elsewhere.

The large biomass of zooplankton in suthern Green Bay is due to constant inputs from the Fox River and is probably enhanced by high recruitment and productivity of zooplankton in the nutrient laden waters of the Fox River water mass. Many species common in the plankton of

Lake Winnebago were transported through the Fox River and established populations in southern Green Bay. Many of these species are rare or entirely absent elsewhere in the Lake Michigan basin.

A brief study on zooplankton distribution in southern Green Bay was conducted by Torke (1972). He sampled 7 stations with a vertical two net on 12 July 1971. He noted that Cyclops vernalis and Diaptomus siciloides were important constituents of the micro-crustacean fauna. The former species is rare in Lake Michigan while the latter has not been reported elsewhere in Lake Michigan.

A few investigations have examined food habits of planktivorous fishes in Green Bay. The previously mentioned study of Norden and Morsell (1968) on alewife food habits included collections in southern Green Bay. Further studies on alewife were conducted by Gannon (1972a) who examined stomach contents of alewife collected off Pensaukee, Wisconsin on 10 July 1969. Large copepods were found to be the predominant food source for alewife. Hogman (1971) examined stomach contents of larval whitefish collected in central Green Bay in May, 1968-1970. Cyclops bicuspidatus was the most prevalent food source followed by Diaptomus spp., Daphnia, and Bosmina.

In summary, our knowledge of Lake Michigan zooplankton has barely advanced beyond basic descriptive natural history. Very little is known concerning the ecology of planktonic Protozoa and Rotifera. Most investigations have concentrated on the larger zooplankton Crustacea. Some knowledge has been gained about their species composition, distribution in space (vertical and horizontal) and time (seasonal), and their importance as food for certain planktivorous fish. Our knowledge of response of zooplankton to specific pollutants and overall changes in water quality is indeed depauperate.

III. ZOOPLANKTON STUDIES IN THE CALUMET AREA

The first samples of Lake Michigan zooplankton made available to science were strained from the City of Chicago water supply by a public works official, B. W. Thomas (Ward 1879). Thomas sent samples of organisms to several experts of the day including E. A. Birge and S. A. Forbes. Birge (1882) and Forbes (1882) both published brief species lists of micro-crustaceans found in the samples. Several of the species (*Diaptomus sicilis*, *Epischura lacustris*, and *Cyclops thomasi*, now known as *C. bicuspidatus thomasi*) reported by Forbes (1882) were new to science at that time. The species lists provided in these two papers are undoubtedly incomplete and many more species have been reported for the Calumet area. Their importance today is primarily as historical documents.

The collection of plankton at the City of Chicago water works, which was begun by B. W. Thomas nearly 100 years ago, has been continued by subsequent workers.

Routine collections and quantitative enumeration of total plankton have been regular procedures in water analysis since 1926. As pointed out earlier, phytoplankton and zooplankton counts are combined, thus rendering these data of little use in analysis of zooplankton information. If zooplankters are specifically mentioned at all, only data for the most common genera of Rotifera, Copepoda, and Cladocera are mentioned (Baylis and Gerstein 1929; Lackey 1944; Damann 1945). Although these data have been adequate for purposes of water filtration plant operation, they are not adequate for detecting long-term changes in zooplankton species composition and abundance commensurate with changes in water quality. Identification of zooplankton to the species level and separation of phytoplankton and zooplankton counts would have been invaluable in augmenting our limited knowledge of zooplankton ecology in the Calumet region.

Williams (1962; 1966) presented quantitative data on abundance and generic composition of predominant rotifers from five water intakes around the Great Lakes including one station at Gary, Indiana (Table B-2). The Gary station exhibited a higher number of rotifer genera (15) than any other station in the Great Lakes, but only the five most abundant genera were identified. The Gary water intake station had relatively high mean numbers of individuals per unit volume and this was correlated with relatively high phytoplankton counts. On the basis of results from 128

Table B-2. Dominant planktonic rotifers from selected Great Lakes sampling stations (Williams, 1966).

Lakes and stations	Rotifers in semimonthly plankton samples, counts/liter, 1961 and 1962							
	Number of genera with 5 or more individuals per sample of 48 samples	Average number per sample of 48 samples	Five most abundant genera of the network--averages for 24 samples from May to November					
			Brachionus	*Keratella*	*Polyarthra*	*Synchaeta*	*Trichocerca*	Total of the 5 genera
Lake Huron, Port Huron, Michigan	11	14.1	0.7	33.1	12.5	1.3	2.5	50.2
Lake Michigan, Milwaukee, Wisconsin	9	63.7	1.2	82.0	45.0	5.9	1.5	135.1
Lake Michigan, Gary, Indiana	15	45.3	0.9	38.6	22.4	3.4	1.9	67.3
Lake Superior, Sault Ste. Marie, Michigan	6	12.0	0.3	4.2	8.0	1.3	0.7	19.6
Lake Superior, Duluth, Minnesota	5	8.5	0	15.2	3.0	1.2	0.3	19.8

stations on water courses throughout the United States, Williams (1966) concluded that high numbers of rotifers were consistently found in waters of high clarity and high phytoplankton concentrations. Zooplankton Crustacea were not identified in his study, but Copepoda averaged three times more abundant than Cladocera in 24 samples collected from July, 1960 to July, 1961 at the Gary, Indiana water intake (Williams 1962).

The investigation by Eddy (1927) was the first attempt to analyze species composition, abundance, and seasonal distribution in the Calumet area of Lake Michigan. He obtained samples from Lake Michigan in November through December, 1887; April through October, 1888; October, 1926; and May and July, 1927. This paper contains the most complete species list of planktonic Protozoa, Rotifera, Cladocera, and Copepoda available for the Calumet area of Lake Michigan. He reported 9 species of non-photosynthetic protozoans, 16 species of rotifers, 11 cladocerans, and 9 copepods. Most species were typical of limnetic conditions, but some littoral and benthic forms were also present because collections were made so close to shore.

The list of species presented by Eddy (1927) is difficult to interpret because of subsequent changes in taxonomic nomenclature. For example, Eddy listed the cladoceran, Bosmina longispina, in his collections.

Wells (1960) only found Bosmina longirostris in his study off the eastern coast of Lake Michigan in 1954-55. Based upon the results in these two studies, Beeton (1965) suggested that B. longispina (=? B. coregoni) was replaced by B. longirostris in Lake Michigan and used this alleged species shift as an indicator of advancing eutrophication. However, because of taxonomic problems in the genus Bosmina (Deevey and Deevey 1971) and since Eddy's samples have evidently been discarded long ago, the exact identity of his Bosmina longispina remains unknown and this indication of advancing eutrophication must be considered dubious.

Likewise, Brooks (1969) attempted to determine shifts in abundance of various Lake Michigan zooplankters between 1927 and 1954 by comparing data of Eddy (1927) and Wells (1960). He suggested that there had been a shift toward zooplankton that are larger and more efficient at filtering phytoplankton between 1927 and 1954. He further suggested that the larger zooplankters, due to their effectiveness in cropping phytoplankton, may be ". . .a factor in the preservation of the oligotrophic condition of that lake." (Brooks 1969). However, Eddy (1927) and Wells (1960) sampled entirely different portions of Lake Michigan using widely divergent methods of collection. Any conclusions drawn from these data on changes in zooplankton populations in Lake Michigan should be viewed as extremely tenuous.

Further difficulties in the interpretation of Eddy's (1927) study also exist. The 1887-88 data were treated only qualitatively while some quantitative information was given for the 1926-27 collections. Any changes in abundance or distribution between the two series of collections are not readily detectable. Samples during the important winter months were lacking so the information on seasonal distribution of many species is incomplete. Although this paper was a landmark in plankton investigations of large lakes, its utility in interpretation of relations between zooplankton population dynamics and water quality changes in the Calumet area of Lake Michigan is limited.

A brief study was conducted in fall, 1970 by Industrial Bio-test Laboratories, Inc. (1971) on the effects of a thermal plume on zooplankton species composition and distribution. The plume of hot water was from the Bailey electric power generating station near Gary, Indiana. The thermal plume at this plant remained as a contiguous water mass because the plume area was protected from prevailing winds and current action by a large breakwater. Total numbers of zooplankton Crustacea were substantially higher inside the plume than in an area beyond the plume's influence. Cladocerans (mainly *Daphnia retrocurva* and *Bosmina longirostris*) and the calanoid copepod, *Eurytemora affinis*, were noticeably more abundant inside the plume than outside it. Further studies would be required to disclose if this is a prominent and consistent feature of heated water plumes in the Calumet area.

The investigation by Johnson (1972) contains the most pertinent information on zooplankton species composition, inshore distribution, and abundance available for the Calumet area. Stations were sampled along three transects off Gary, Burns Harbor, and Michigan City, Indiana on seven dates from June through October, 1970 (Figure B-2). A small Wisconsin plankton net with 76 μm mesh size was used as the collecting device. The small diameter of the net and the fine mesh size possibly biased these data since larger species of zooplankton Crustacea are capable of net avoidance. In addition, clogging of the fine mesh by phytoplankton likely reduced the filtration efficiency of the net. Consequently, calculations of zooplankton abundance may be low by as much as 50 percent (Gannon 1972a).

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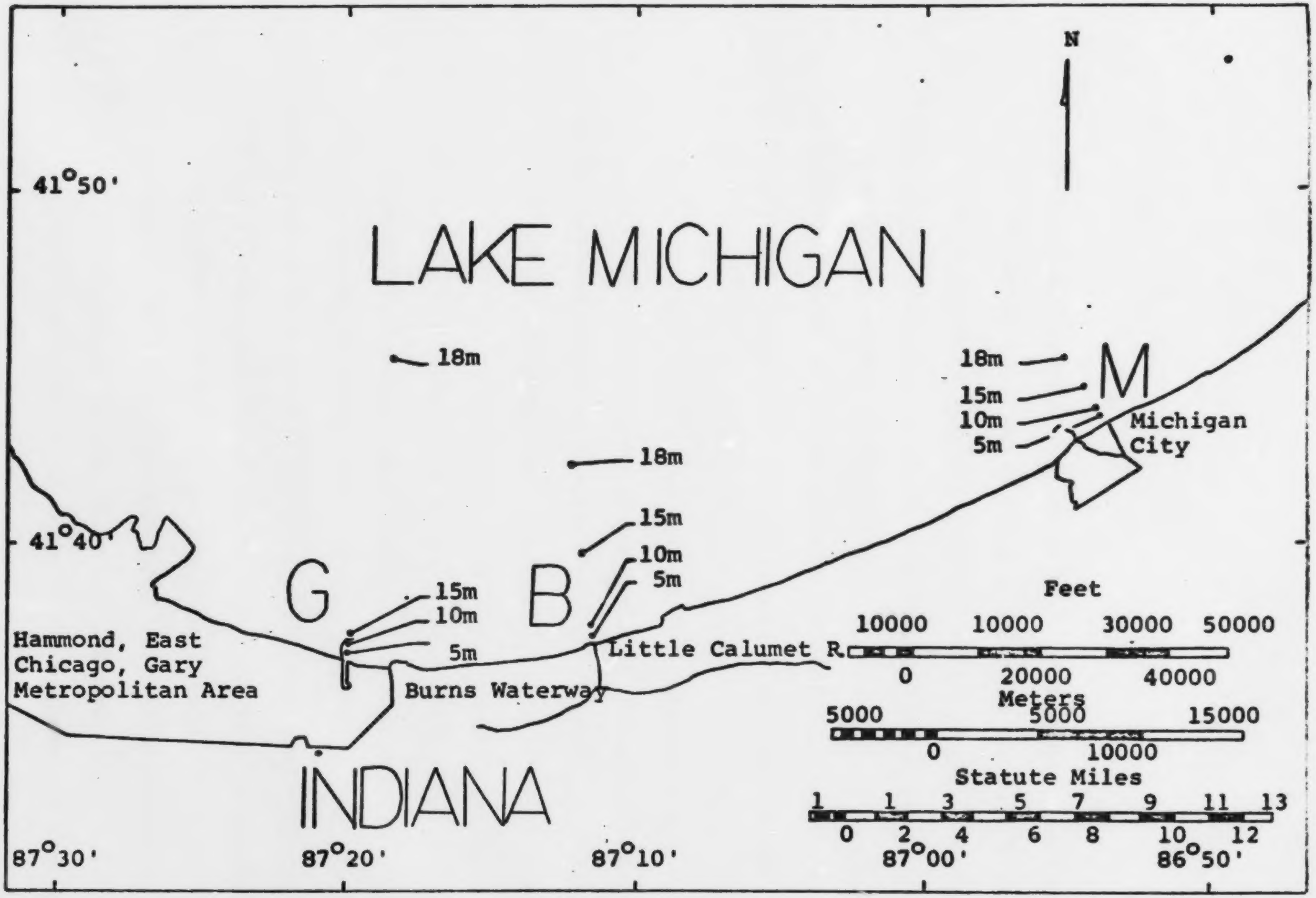
N
41°50'
LAKE MICHIGAN
18m
18m
18m
15m
10m
5m
M
Michigan City
15m
10m
5m
41°40'
G
15m
10m
5m
B
Feet
10000
10000
30000
50000
Hammond, East Chicago, Gary Metropolitan Area
Little Calumet R.
0
20000
40000
Burns Waterway
Meters
5000
5000
15000
0
10000
Statute Miles
1
1
3
5
7
9
11
13
0
2
4
6
8
10
12
INDIANA
87°30'
87°20'
87°10'
87°00'
86°50'

Figure B-2. Indiana waters of Lake Michigan showing sampling stations along transects from Gary (G), Burns Ditch (B), and Michigan City (M), Indiana at depths of 5, 10, 15, and 18 m. (From Johnson 1972)

Johnson (1972) recorded 10 species of Copepoda and 14 species of Cladocera and Rotifera in the study area (Table B-3). Bosmina longirostris, Daphnia retrocurva, and Cyclops bicuspidatus were the most abundant crustacean zooplankters throughout the study period (Figures B-3, B-4 and B-5). There were few consistent patterns in zooplankton abundance and distribution between the three transects. However, biomass of zooplankton Crustacea was generally higher at Michigan City and Gary stations than at Burns Harbor (Figures B-6, B-7, B-8). Although sampling methods employed in this study may have underestimated population numbers, the abundance of zooplankton at all stations in the Indiana waters were considerably higher than values reported for elsewhere in Lake Michigan. Total numbers of zooplankton Crustacea in the Indiana waters ranged from about 225,000 to 375,000 individuals per m^3. These values are approximately 10 times higher than biomass figures reported for the offshore waters of Lake Michigan (Wells 1960; Gannon 1972a), and two to three times higher than values reported by Eddy (1927) for a sample collected near Chicago, Illinois on 10 July 1927. Comparable numbers have been reported only in Milwaukee Harbor, at the mouth of the Fox River in Green Bay (Gannon 1972a), and near the southwestern shore of Lake Michigan (Roth and Stewart 1973).

The zooplankton Crustacea community in the Indiana waters was characterized by low numbers of calanoid copepods relative to cyclopoid copepods and cladocerans. Phenomenally

Table B-3. List of zooplankton found in the Indiana waters of Lake Michigan during 1970 (from Johnson 1972).

COPEPODA

CALANOIDA

- *Diaptomus ashlandi*
- *Diaptomus minutus*
- *Diaptomus oregonensis*
- *Diaptomus sicilis*
- *Eurytemora affinis*
- *Epischura lacustris*
- *Limnocalanus macrurus*

CYCLOPOIDA

- *Cyclops bicuspidatus thomasi*
- *Tropocyclops prasinus*

HARPACTICOIDA

- *Canthocamptus* sp.

CLADOCERA

- *Bosmina longirostris*
- *Bosmina coregoni*
- *Chydorus sphaericus*
- *Eurycercus lamellatus*
- *Alona affinis*
- *Holopedium gibberum*
- *Leptodora kindtii*
- *Polyphemus pediculus*
- *Diaphanosoma leuchtenbergianum*
- *Ceriodaphnia* sp.
- *Daphnia retrocurva*
- *Daphnia galeata-mendotae*
- *Daphnia longiremis*
- *Daphnia pulex*

Table B-3. (Continued)

ROTIFERA

Polyarthra vulgaris
Keratella cochlearis
Keratella quadrata
Kellicottia longispina
Synchaeta sp.
Gastropus sp.
Trichocerca sp.
Asplanchna priodonta
Ploesoma truncatum
Pompholyx sp.
Filinia longiseta
Brachionus angularis
Brachionus calyciflorus
Notholca sp.

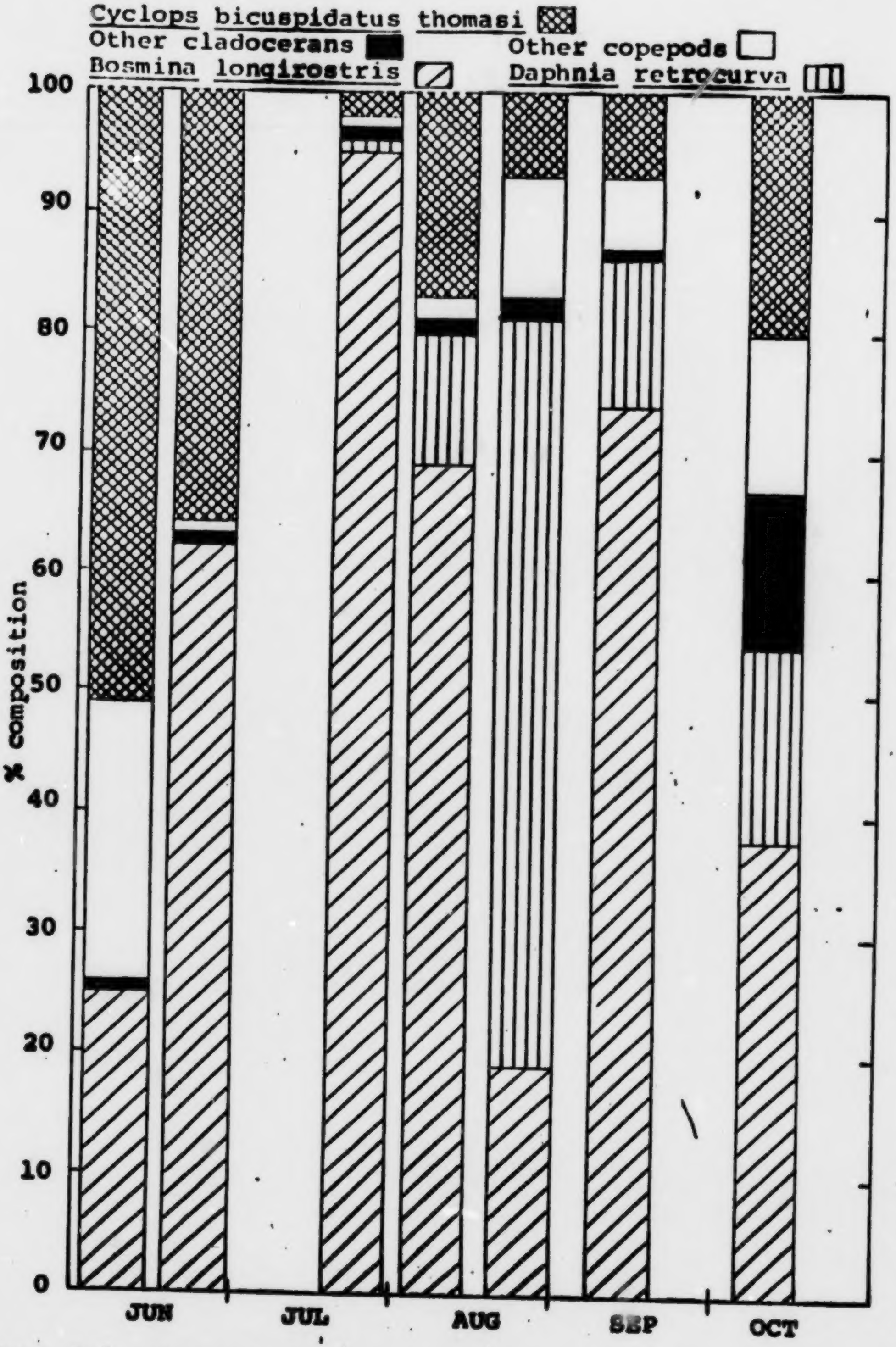

Figure B-3. Percent species composition of adult crustacean zooplankters as a mean of all stations on the Michigan City transect in Indiana waters of Lake Michigan, 1970 (from Johnson 1972).

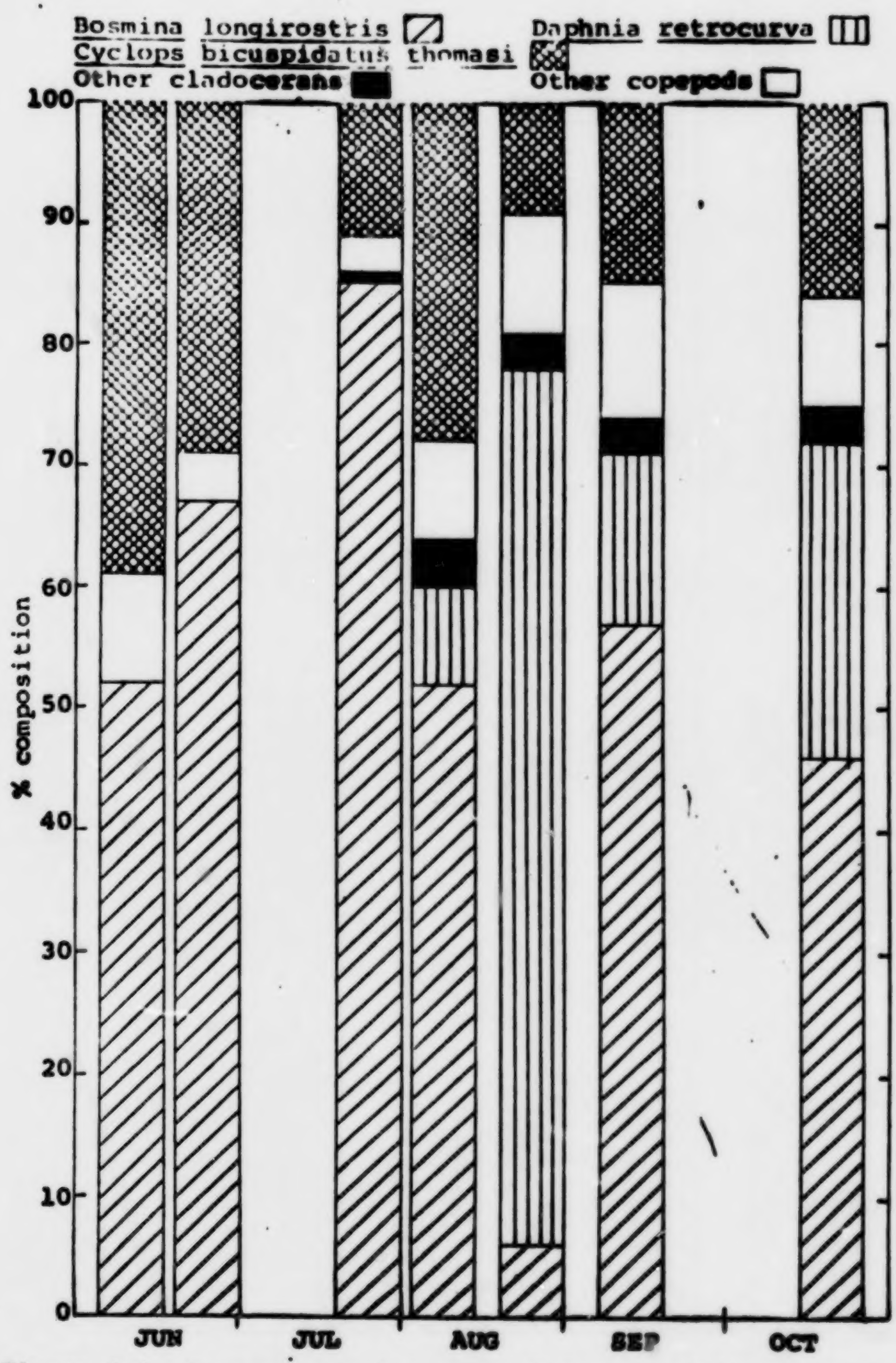

Figure B-4. Percent species composition of adult crustacean zooplankters as a mean of all stations on the Burns Ditch transect in Indiana waters of Lake Michigan, 1970 (from Johnson 1972).

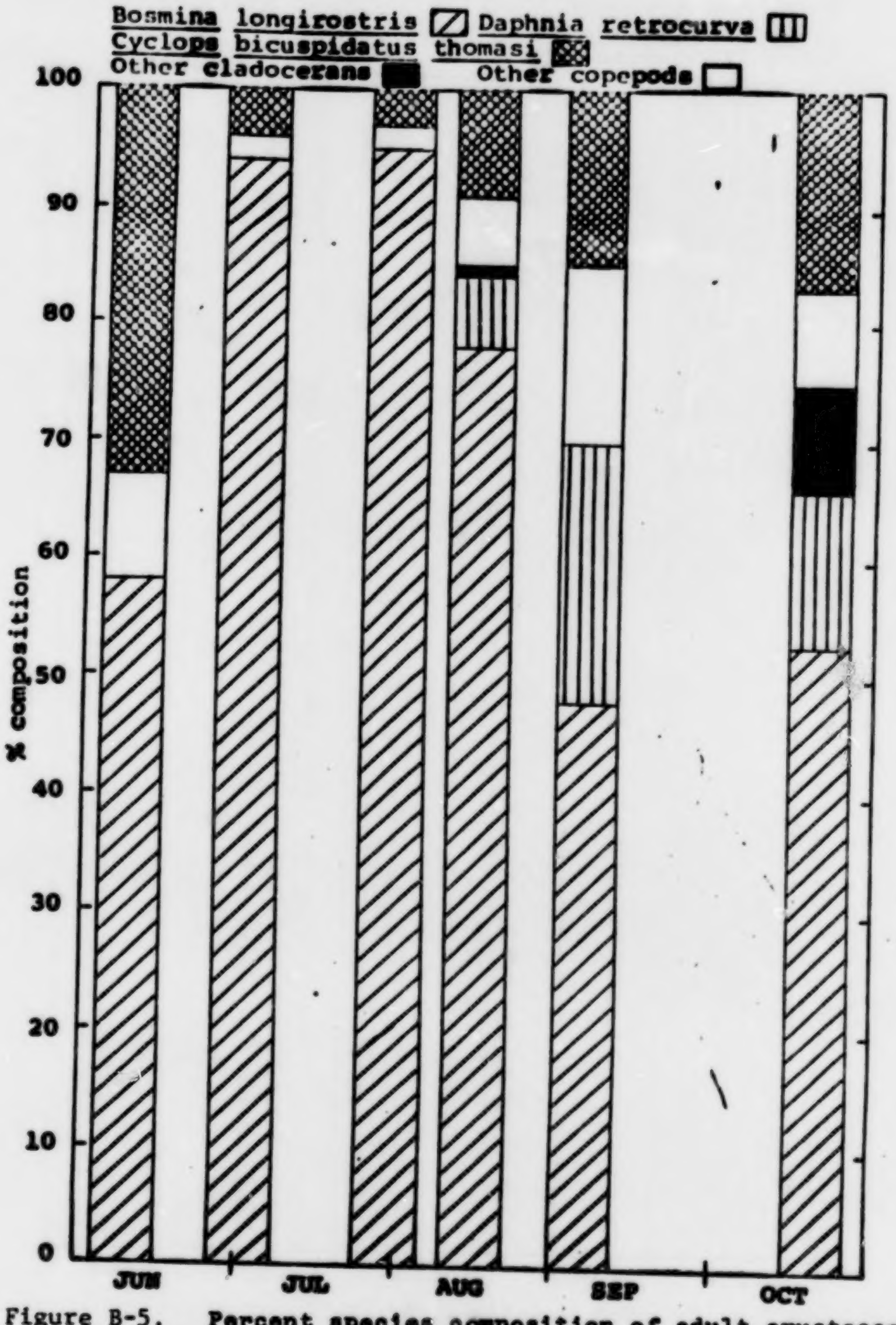

Figure B-5. **Percent species composition of adult crustacean zooplankters as a mean of all stations on the Gary transect in Indiana waters of Lake Michigan, 1970 (from Johnson 1972).**

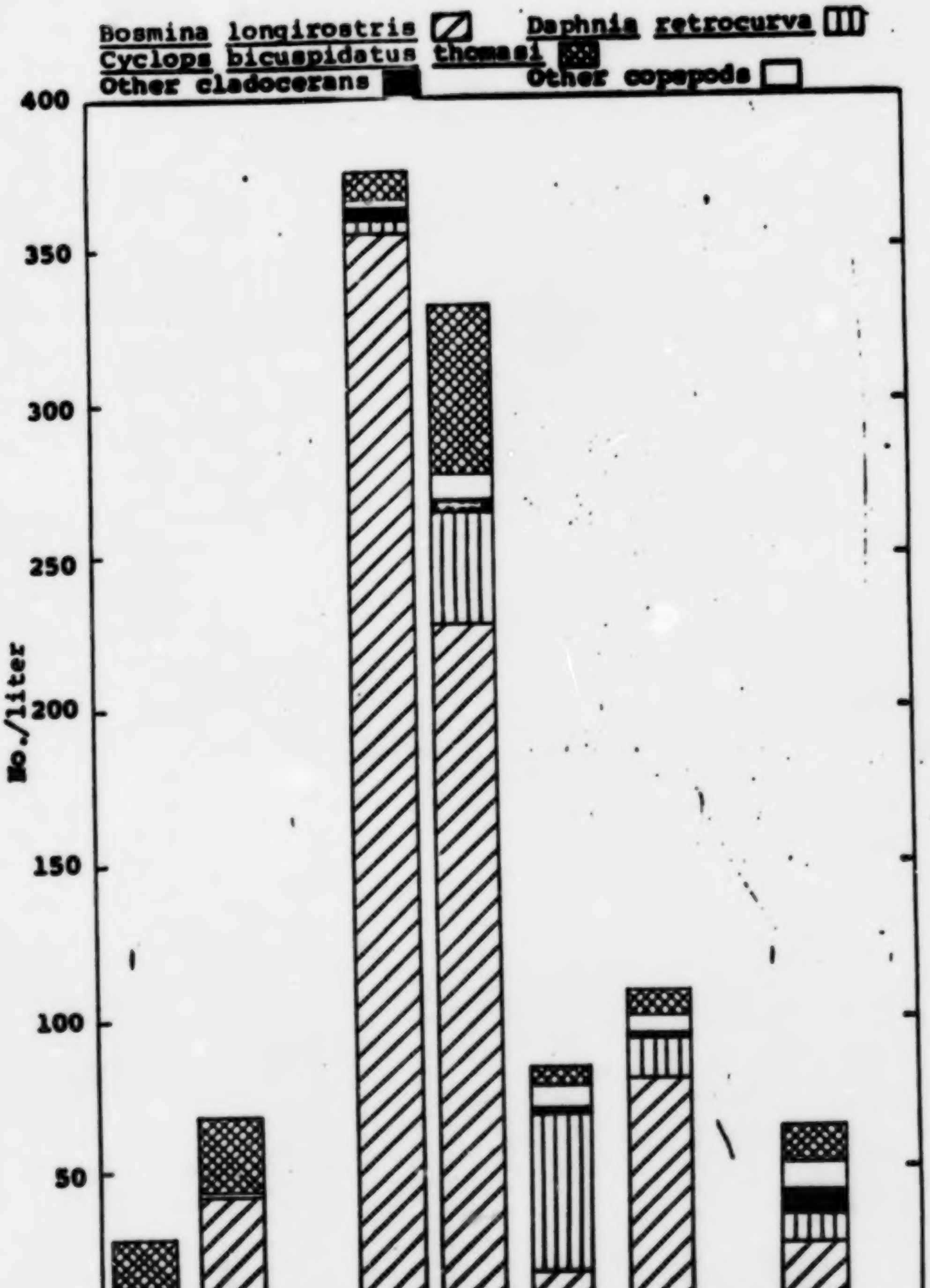

Figure B-6. Abundance of adult crustacean zooplankters as a mean of all stations on the Michigan City transect in Indiana waters of Lake Michigan, 1970 (from Johnson 1972).

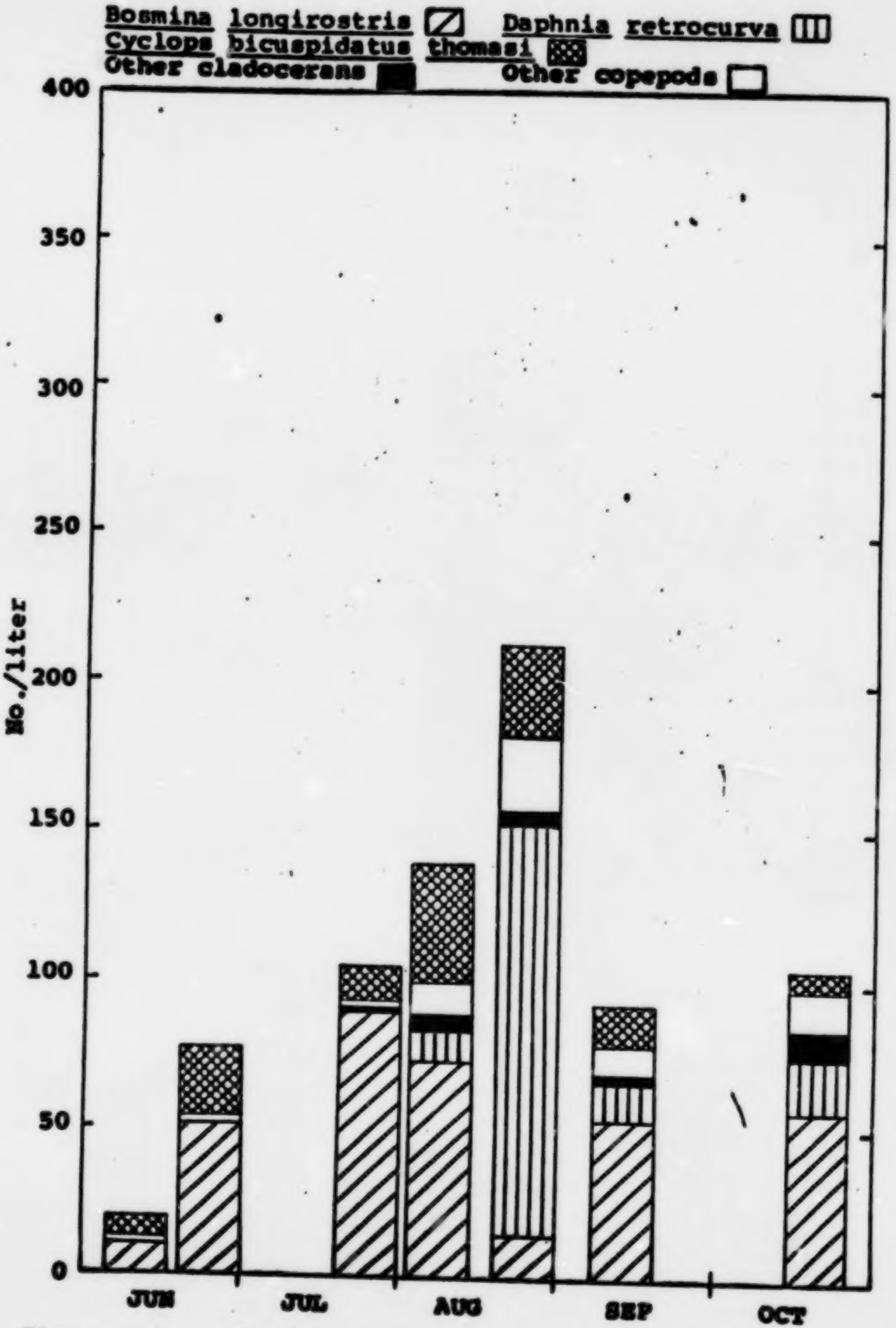

Figure B-7. Abundance of adult crustacean zooplankters as a mean of all stations on the Burns Ditch transect in Indiana waters on Lake Michigan, 1970 (from Johnson 1972)

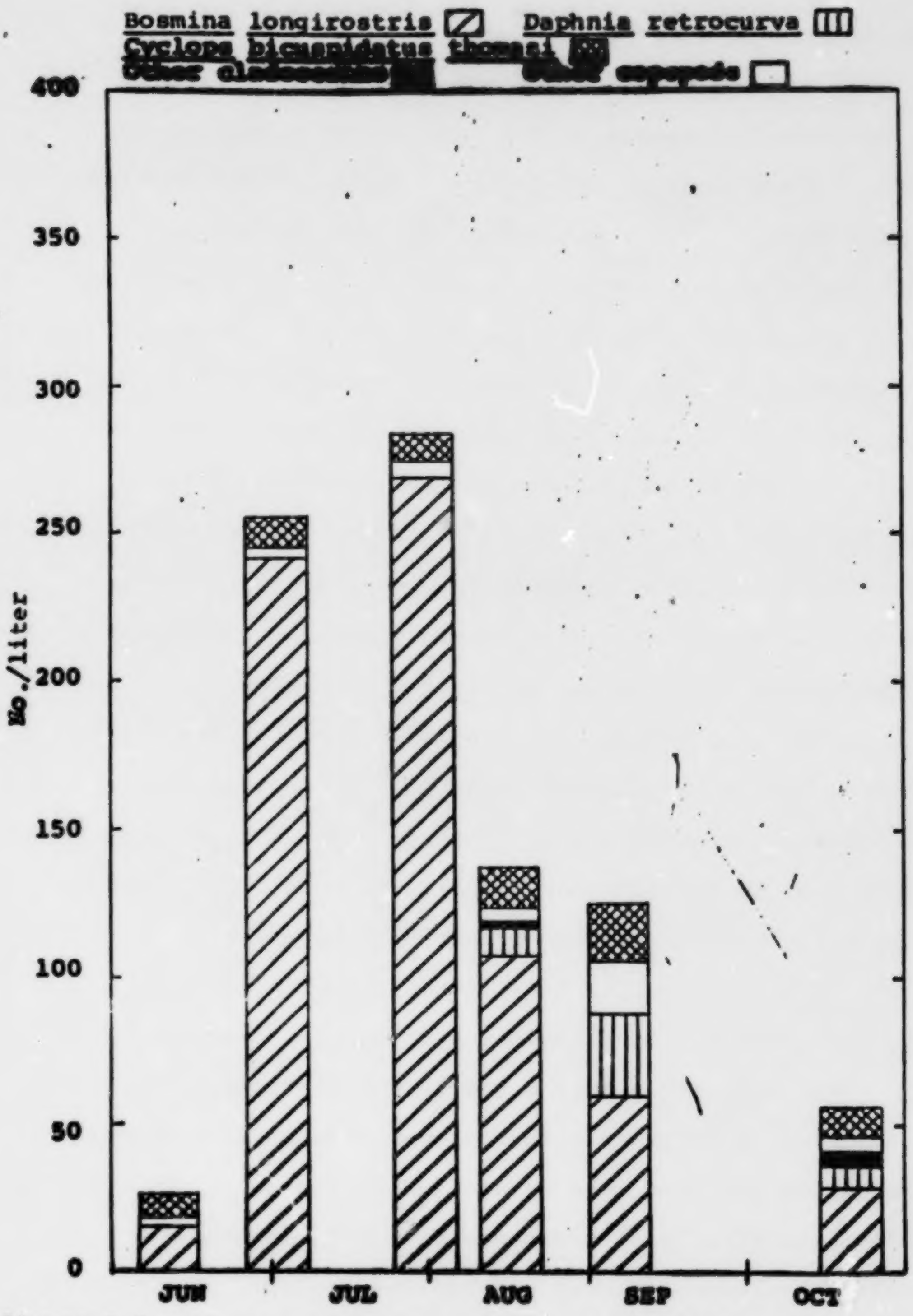

Figure B-8. Abundance of adult crustacean zooplankters as a mean of all stations on the Gary transect in Indiana waters of Lake Michigan, 1970 (from Johnson 1972).

high numbers of a few species of cladocerans and cyclopoid copopods coupled with low numbers of calanoid copepdods may indicate a response by the zooplankton community to nutrient enrichment of the Indiana waters of Lake Michigan (Gannon 1972b). The dominance of smaller species and individuals of zooplankton Crustacea in the Indiana waters may be the result of heavy alewife predation. This conclusion is augmented by the work of several investigators who found Cladocera and Copepoda to be predominate food sources of alewife in the Indiana waters of Lake Michigan (Rhodes 1971; Webb 1973; Webb and McComish 1974; Rhodes and McComish 1975).

Johnson (1972) reported 12 genera of Rotifera in the Indiana waters of Lake Michigan (Table B-3) Polyarthra was most abundant followed by Keratella, Synchaeta, Kellicottia, and Trichocerca (Table B-4). Mean numbers of rotifers per sample were over 100,000 individuals per m^3. These values were approximately 7 times higher than those reported by Eddy (1927) for a July, 1927 sample off Chicago, Illinois. The high numbers of rotifers recorded in 1970 in the Indiana waters of Lake Michigan may indicate a response of the rotifer community to nutrient enrichment.

The only study that has examined the impact of potential pollutants from the Calumet area on Lake Michigan zooplankton was conducted by Gannon and Beeton (1969). They studied the effects of sediments from nine Great Lakes harbors, including Calumet and Indiana Harbors, on mortality of crustacean zooplankters. The investigation was conducted

Table B-4. Mean abundance of rotifers in numbers per liter on Michigan City, Burns Ditch, and Gary transects in Indiana waters of Lake Michigan, 1970 (from Johnson 1972).

Transect	Mean no. of rotifers per sample	Mean of the five most common genera per sample					Total mean of five most common genera per sample
		Polyarthra	*Keretella*	*Synchaeta*	*Kellicottia*	*Trichocerca*	
Michigan City	109	45	38	8	9	4	104
Burns Ditch	124	51	41	13	10	2	117
Gary	128	42	49	21	5	2	119

in the laboratory using sediments collected from five stations in Calumet Harbor (Figure B-9) and Indiana Harbor (Figure B-10) and from one to five samples in the other Great Lakes harbors. Two sets of experiments were run: one using a laboratory culture of *Daphnia pulex* and the other using freshly collected Lake Michigan zooplankton. In both tests, the zooplankters were placed in 125 ml bottles with different concentrations of suspended sediments. After 48 hours, counts of live and dead organisms were made.

Results of the *Daphnia pulex* and natural Lake Michigan zooplankton tests were similar. In Calumet Harbor, significant mortality occurred in the river sediment samples but no significant mortality occurred in the outer harbor (C-1) sample (Figures B-11 and B-12). The sediment from the outer harbor of Calumet was one of the least toxic sediments encountered in the study. This harbor differed from others included in the investigation since Lake Michigan water flows into the Calumet River. Consequently, there is a continuous influx of relatively high quality water into the outer harbor. In Indiana Harbor, highest mortality of zooplankton was observed at the innermost stations (Figures B-11 and B-12). Indiana Harbor samples were among the most toxic to plankton and benthos encountered during the study. No attempt was made in this investigation to identify the toxic substances responsible for the zooplankton mortalities. However, mortalities were generally greatest in samples exhibiting an oily texture and a high chemical oxygen demand (Gannon and Beeton 1969).

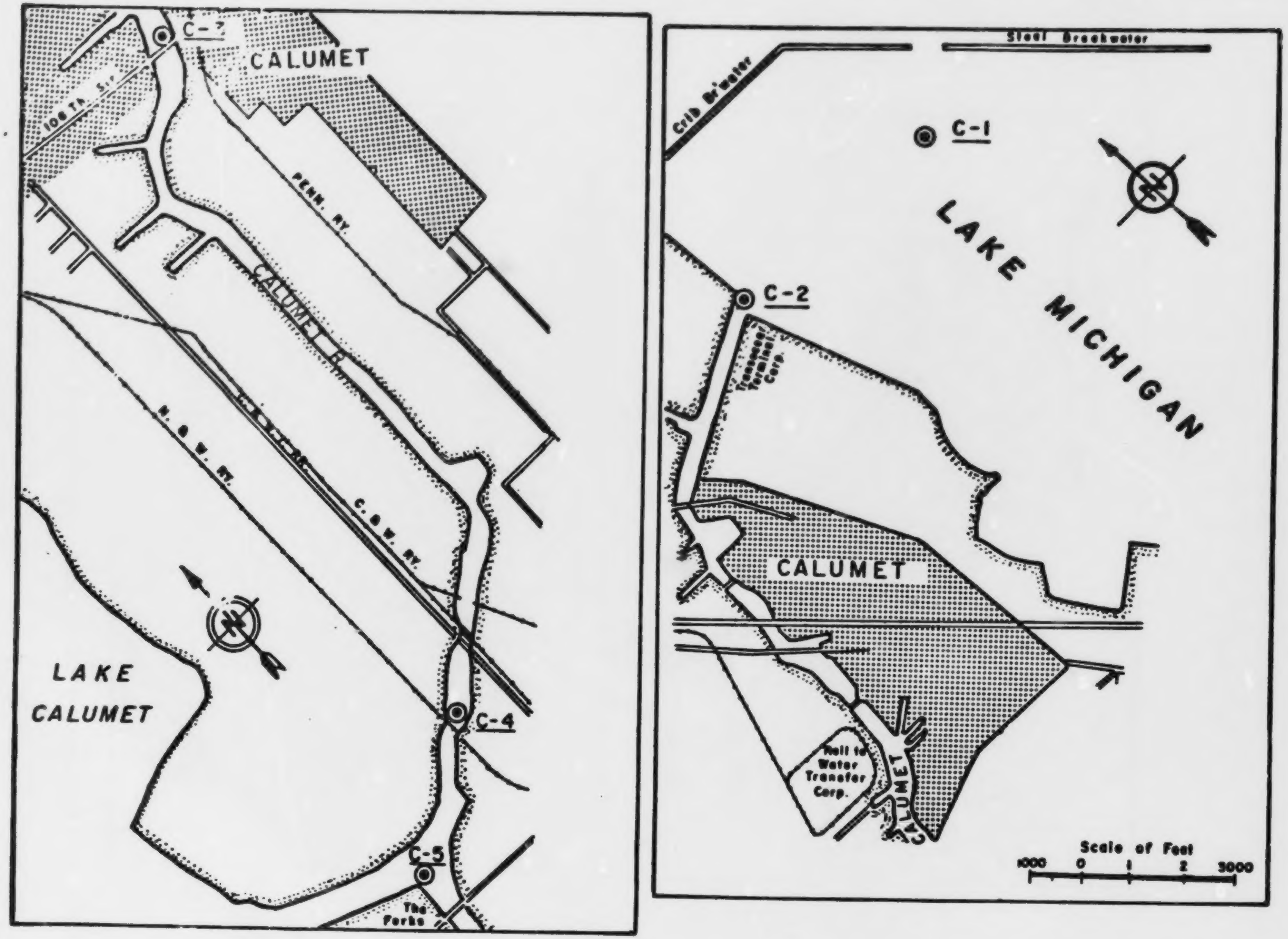
C-3
CALUMET
106 TH. ST.
PENN. RY.
CALUMET R.
N.&W. RY.
C.&W. RY.
LAKE
CALUMET
C-4
C-5
The Forks
Steel Breakwater
Crib Br'water
C-1
LAKE MICHIGAN
C-2
Transocean Terminal Corp.
CALUMET
Rail to Water Transfer Corp.
CALUMET
Scale of Feet
1000
0
1
2
3000

Figure B-9. Location of sampling points, 1968, Calumet river (from Gannon and Beeton 1969).

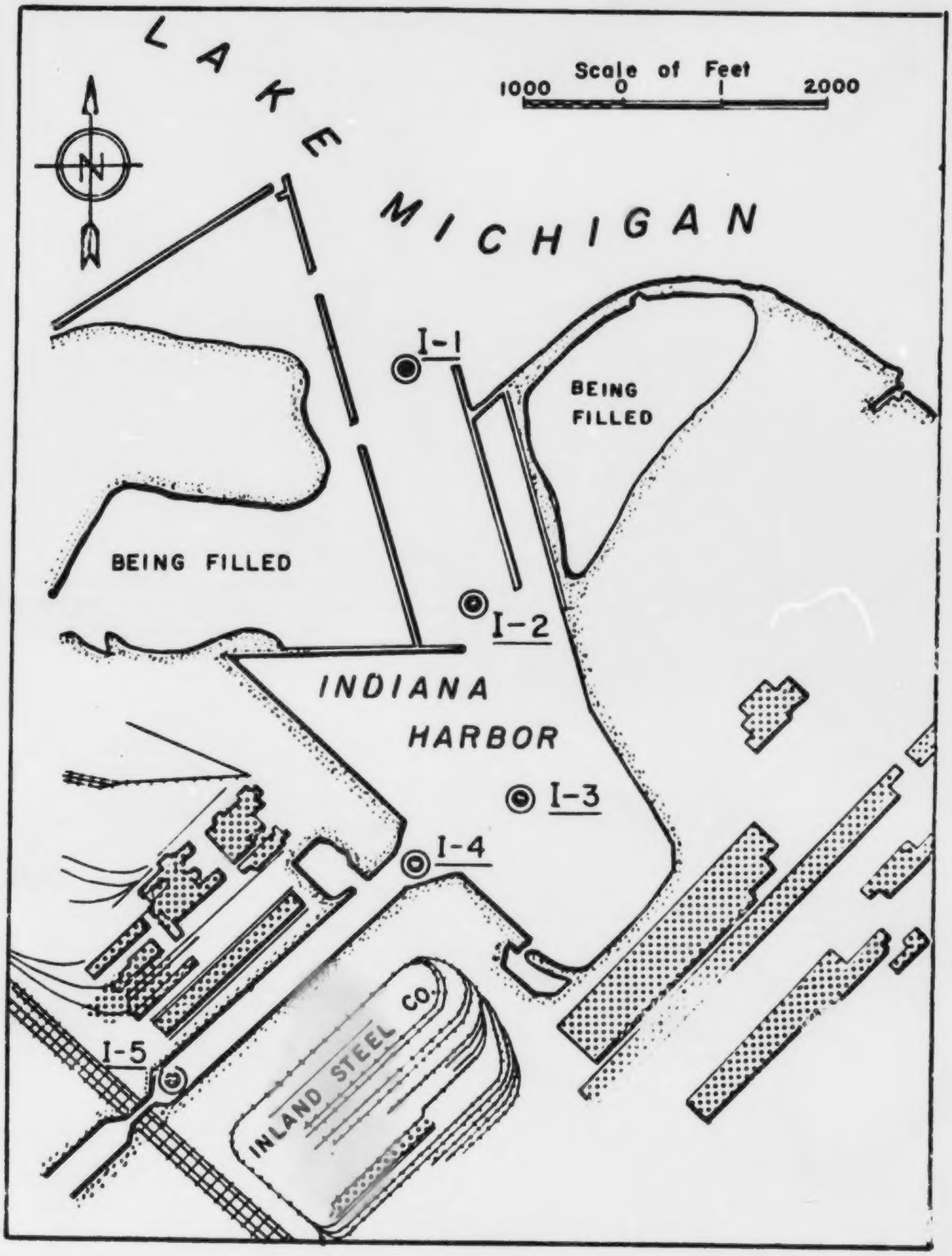
LAKE MICHIGAN
N
Scale of Feet
1000
0
1
2000
I-1
BEING FILLED
BEING FILLED
I-2
INDIANA HARBOR
I-3
I-4
I-5
INLAND STEEL CO.

Figure B-10. Location of sampling points, 1968, Indiana harbor (from Gannon and Beeton).

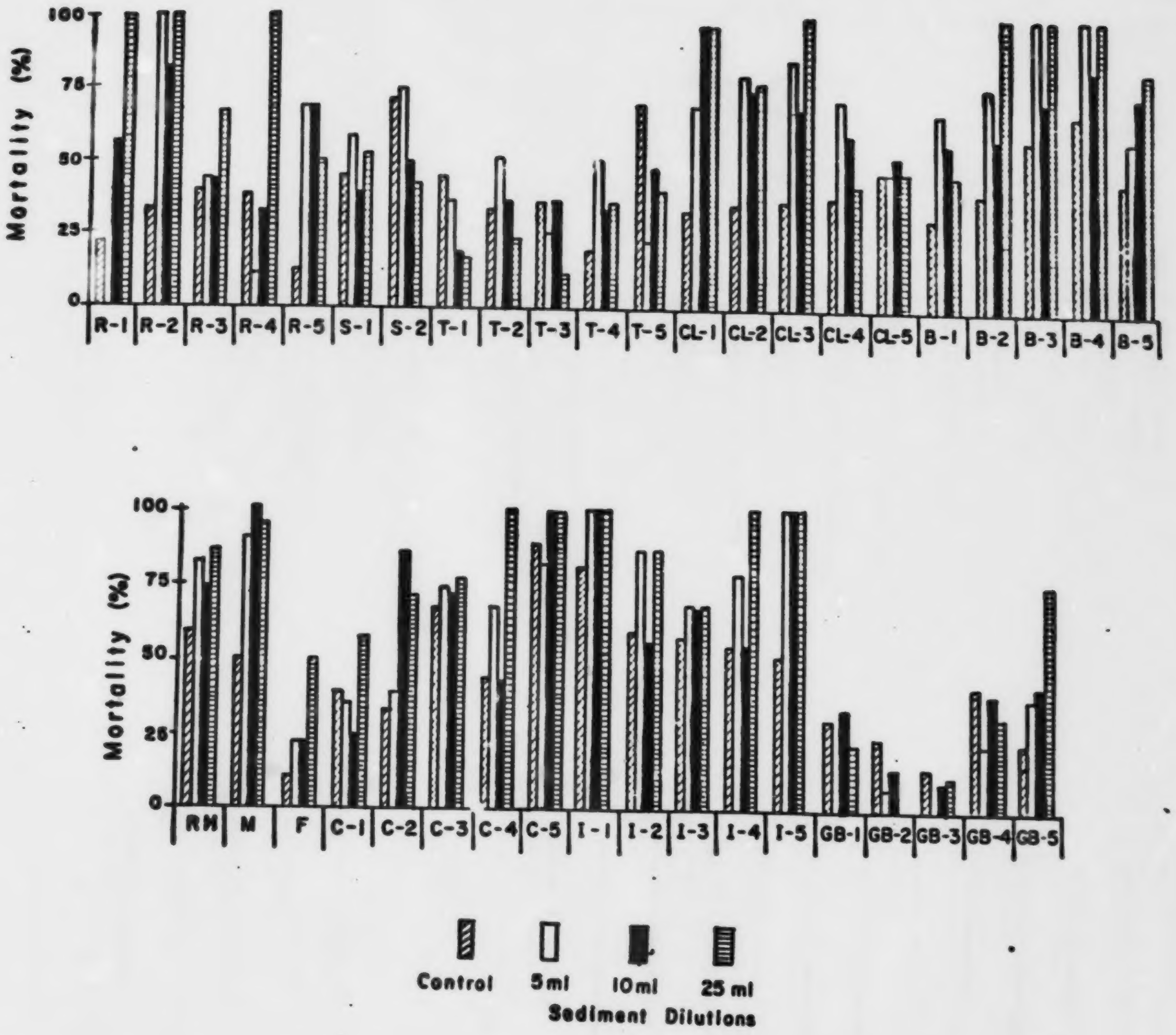

Figure B-11. Mortality of Daphnia pulex in various concentrations of harbor sediments (B, C, CL, GB, I, M, R, RH, S, and T) and Fuller's Earth (F). Calumet Harober (C) and Indiana Harbor (I) (from Gannon and Beeton 1969).

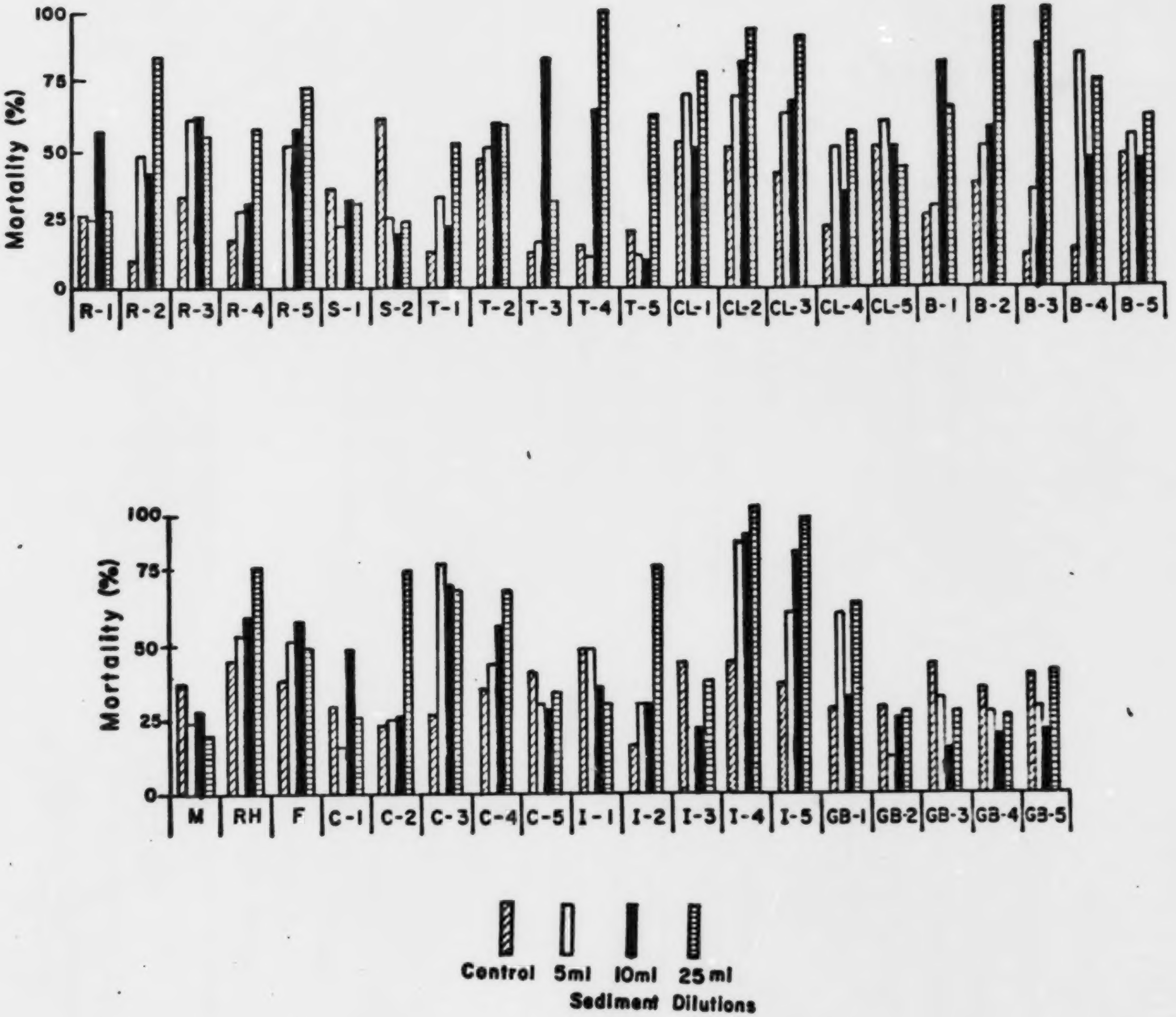

Figure B-12. Mortality of zooplankton in various concentrations of harbor sediments (B, C, CL, GB, I, M, R, RH, S, and T) and Fuller's Earth (F). (from Gannon and Beeton 1969).

IV. IDENTIFICATION OF DATA GAPS AND RECOMMENDATIONS FOR ZOOPLANKTON RESEARCH IN THE CALUMET AREA

It is readily apparent from the previous discussion that our knowledge of zooplankton ecology in the Calumet area of southern Lake Michigan is woefully incomplete. Basic descriptive information on species composition, spatial distribution, and seasonal distribution is inadequate. Undoubtedly, many species of planktonic Protozoa, Rotifera, and Crustacea occur in the Calumet region that have not been previously reported. The zooplankton community in a shallow, estuarine region such as the Calumet area will consist of eulimnetic Lake Michigan species, littoral species, organisms that are predominately benthic but occasionally are found in the plankton, and other species most characteristic of rivers. Stemberger (1973) and Gannon (1972a) have compiled species lists for the Rotifera and Crustacea, respectively, of the Milwaukee River estuary. It is most likely that many zooplankters occurring in the Milwaukee Harbor region may also exist in the Calumet area.

The work of Johnson (1972) has provided some information on horizontal distribution of zooplankton in the near-shore waters of the Calumet area. Seasonal distribution data is available only for the spring, summer, and fall months (Eddy 1927; Johnson 1972). Winter data are needed in the Calumet area to complete our knowledge of this important aspect of zooplankton ecology. Distribution studies on zooplankton ought not be limited to the Lake Michigan portion of the Calumet area alone. Although volumes have been written on pollution problems of the rivers tributary to Lake Michigan in the Calumet area (e.g , U.S. Department of Health, Education, and Welfare 1965), zooplankters have been ignored. The contribution of zooplankton species composition and biomass to the inshore waters of Lake Michigan from tributaries in the Calumet region should be investigated. A background of descriptive information on species composition and distribution must be acquired before questions on the relations between zooplankton community structure and water quality can be tackled.

Studies on the impact of water quality degradation on zooplankton in the Calumet area are practically nonexistent. Zooplankters are known to be sensitive to toxic pollutants (e.g., Anderson 1944). The extreme reduction or absence of zooplankters in a given area will be a good indication of toxic pollution. On the other hand, certain species of zooplankton respond to nutrient loading with faster growth rates and build up phenomenally high numbers of individuals in a short time. High numbers of a few species in a certain region will be a good indication of nutrient enrichment. For example, Johnson (1972) noted that Bosmina longirostris was often the most abundant crustacean zooplankter in the Indiana waters of Lake

Michigan. Gannon (1972a) observed such high numbers of this species only in the nutrient enriched waters at the mouths of the Milwaukee and Fox Rivers. Consistently high numbers of Bosmina and other zooplankters in the Indiana waters of Lake Michigan may indicate that nutrient loading has a greater effect on the zooplankton population than discharge of toxic wastes.

The following types of zooplankton studies are recommended for applied research in the Calumet area:

1) An examination of plankton records at the City of Chicago Department of Water and Sewers would be desirable. If it is possible to separate phytoplankton and zooplankton counts, valuable information on changes in zooplankton abundance with time may be discernable.

2) Field studies on the species composition and distribution of zooplankton in the Calumet region. These investigations should include stations in the lower portions of the Calumet River complex and Burns Ditch. The purpose of such studies should be to identify areas where the zooplankton community is responding to toxic wastes and/or nutrient loading. Taxonomic identification to the species level is imperative if worthwhile data are to be gained. Protozoa and Rotifera may provide more valuable information than Crustacea since the smaller organisms have a high reproductive capacity and can respond quicker to environmental changes than the larger Crustacea. Analysis of

zooplankton community structure may be more valuable than looking for single indicator species of water quality. Gannon (1972b) suggested that the relative proportion of calanoid copepods to cladocerans and rotifers may be a useful ratio in indicating changes in water quality of the Great Lakes. Schelske and Roth (1973) successfully used this ratio to characterize zooplankton response to water quality in Lakes Michigan, Superior, Huron, and Erie.

3) Laboratory bioassay studies using zooplankton would be most useful in identifying the response of zooplankton to specific pollutants in the Calumet area. Such studies would be invaluable in setting effluent and water quality standards in the southern Lake Michigan region.

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APPENDIX C

DESCRIPTION OF INDUSTRIAL EFFLUENT SOURCES AND COMPARISON OF EFFLUENT DATA

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DESCRIPTION OF INDUSTRIAL EFFLUENT SOURCES AND COMPARISON OF EFFLUENT DATA

1. INTRODUCTION

This appendix was prepared under a subcontract by Citizens for a Better Environment. It provides more detailed information than was given in Chapter 4 (Vol. I of this report). It contains tables showing the effluent flows and compositions for the major industrial facilities, and compares effluent data from NPDES permit applications with industry monthly operating reports, and 24-hr effluent sampling done by Indiana and U.S. EPA. In the case of two industries, it presents the effluent performance that is being implemented as a result of court-enforced agreements.

Table 4.1 and Figure 4.1 in Chapter 4 locate the industries and effluent sources in the Calumet area. Chapter 4 contains summary tables giving the loads of major pollutants from all outfalls to Lake Michigan, as well as summary tables of loads from all outfalls entering Lake Michigan via the IHC. More detailed tables of loads from outfalls on the IHC are presented in the Combinatorics (1974) report, and some of these tables have been included in Chapters 13 to 18. This appendix contains further detailed data on large industrial facilities discharging to the IHC. In general there is reasonable agreement with Combinatorics (1974).

Information on the various effluent sources was gathered primarily from U.S. EPA files, NPDES permit applications, Indiana Stream Pollution Control Board files and in some instances from the industries concerned. Although this appendix represents an extensive compilation of data, it by no means contains all the relevant data available.

Wide discrepancies have been noted in the amount of data available on each effluent source. Generally, the more serious the pollution, the more available is source data. For many minor industrial discharges, often the only data available are in the NPDES permit application.

Of the various data sources utilized, perhaps the NPDES permit application data when used in conjunction with the U.S. EPA file is the most valuable. The NPDES application includes detailed information relating to the effluent discharge including flow, parameter concentrations and treatment methods. Additional information from the U.S. EPA file can be used to update the NPDES and offer more detailed information relating to waste treatment facilities and the industry's litigation record. EPA surveillance reports are also available in these files and can be used as a cross-check on NPDES data. The NPDES applications were originally submitted in mid-1971, based on measurements made in late 1970.

The files of the Indiana Stream Pollution Control Board are useful primarily for ISPCB effluent surveillance reports. These reports are filed approximately once a year and can be used to cross-check NPDES data and observe more recent changes in effluent quality. Also in ISPCB files are monthly operating reports filed by the industries. These data can be used as a cross-check, but often very few outfalls and parameters are reported. In the tables in this appendix we used only the most recent monthly operating reports (April and May 1973) for comparison with NPDES data, since these reports should reflect the most up-to-date effluent conditions.

Information from industries was valuable and often provided further clarification.

2. AMERICAN MAIZE COMPANY

2.1 Introduction

American Maize Company located in Hammond, Indiana, produces cornstarch and corn syrup from shelled corn (NPDES application).

2.2 Data Evaluation

The company has six discharges, one into Lake Michigan and five others into the Wolf River Channel which flows into the Wolf Lake. Table C-1 indicates discharge location, flow and usage.

Outfall 001 discharges into Lake Michigan with treated process waste water. The plant effluent is typically high in BOD, but after biological treatment, installed in 1969, BOD is reduced to an average of 13 mg/ℓ as reported in the July 1973 ISPCB Monthly Operating Report. Ammonia-nitrogen and total phosphorus values reported in the NPDES Application are 1.57 mg/ℓ and 0.51 mg/ℓ, respectively. These, however, are not included in monthly operating reports to the ISPCB, therefore, no accurate data are available concerning their present discharge concentration. Effluent data for discharge 001 are included in Table 4.2, Chapter 4.

Discharges 002-005 are indicated in the NPDES application to be noncontact cooling water. Consequently, American Maize has not submitted parameter data other than flow, pH, temperature, and chlorine as OCl^-. Waste treatment at this plant consists of two primary settling tanks, an aerated lagoon used as an activated sludge unit, a clarifier and two additional aerated lagoons from which the final effluent flows to Lake Michigan. The monthly operating reports submitted to the ISPCB indicate that batch processes may cause peak effluent concentrations to occur once or twice a month. These reports show peak COD and BOD concentrations of several times the average. This may explain a light-colored plume from American Maize seen in Lake Michigan during the IITRI aerial surveillance.

Table C-1

AMERICAN MAIZE DISCHARGES

Discharge	Flow MGD	Location	Water Usage
001	9.7	Lake Michigan	Process
002	0.216	Wolf River Channel	Cooling Water
003	0.057	" " "	" "
004	0.288	" " "	" "
005	0.086	" " "	" "
Unnumbered	0.242	Wolf Lake	excess intake

3. AMERICAN OIL COMPANY

3.1 Introduction

The American Oil Company (AMOCO) facility in Whiting, Indiana, is a "Class D" oil refinery which performs lube oil processing, topping and cracking/reforming operations. Crude oil is processed into various products at an established capacity of 330,000 barrels/day. Processes utilized include distillation, catalytic reforming, hydrodesulfurization, catalytic cracking, alkylation, treating, extraction, dewaxing, grease and lube oil production, coking, asphalt production and sulfur recovery (EPA permit application file 1973).

3.2 Data Evaluation

Water use within the facility is for both process and noncontact cooling water amounting to a combined discharge of 128 mgd. Outfalls are shown in Figure C-1. Outfall 001 is the treated process waste stream with a flow rate of 29.17 mgd. NPDES BOD values average 20.0 mg/ℓ; NH_3-N 5.43 mg/ℓ; oil and grease 4.8 mg/ℓ and phenols, 0.249 mg/ℓ. Additional parameters are included in Table 4.2. These values substantially agree with ISPCB monthly operation reports for the later half of 1973. Nitrogen values, however, are consistently 2-3 mg/ℓ lower than reported on the NPDES (see Table C-2).

Outfall 002 is noncontact cooling water with a flow of 99 mgd. Continuous monitoring is conducted to insure stream continuity. NPDES average effluent concentrations for various parameters are BOD, 4 mg/ℓ; NH_3-N 0.06 mg/ℓ; total organic carbon, 20 mg/ℓ; oil and grease, 0.9 mg/ℓ and phenols, 0.031 mg/ℓ (see Table C-2). ISPCB monthly operating reports (in Table C-2) indicate values somewhat lower for each parameter than those listed on the NPDES.

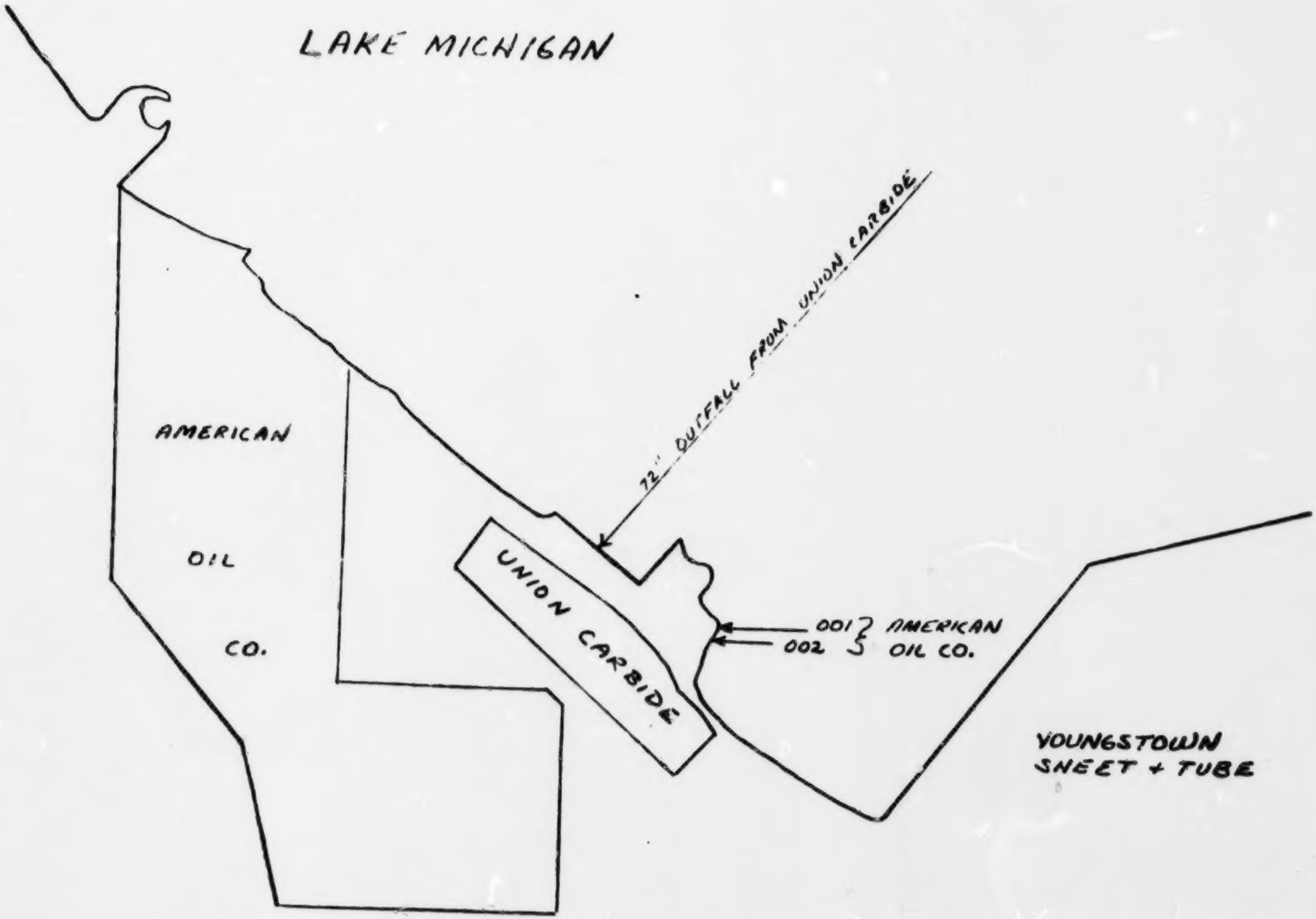

LAKE MICHIGAN
72" OUTFALL FROM UNION CARBIDE
AMERICAN
OIL
CO.
UNION CARBIDE
001
002
AMERICAN OIL CO.
YOUNGSTOWN
SHEET + TUBE

Figure C-1

DETAIL MAP SHOWING OUTFALLS
FROM AMERICAN OIL CO. AND UNION CARBIDE

Table C-2

AMERICAN OIL COMPANY OUTFALL 002 DATA COMPARISON

	Parameters, mg/ℓ			
	BOD	NH_3-N	PHENOL	OIL
NPDES APPLICATION	4.0	0.06	0.03	0.9
ISPCB MONTHLY OPERATING REPORT APRIL, 1973	1.0	0.015	0.06	0.6
ISPCB MONTHLY OPERATING REPORT MAY, 1973	2.1	0.01	0.03	0.71

3.3 Waste Treatment

In-plant changes to reduce the pollution load include recycle of decoking water, the sale of spent caustic and acids, stream stripping of sour water and reuse of phenolic water bottoms. The process waste water treatment area includes 20-24 API separators of a two-stage type with a detention time of approximately 120 min. Process effluent from the separator goes to a gravity settling lagoon where it flows into an aerated lagoon consisting of four compartments in series. The aerated lagoon effluent is coagulated with alum, flocculated using polyelectrolytes as flocculating aids, followed by air flotation before release to Lake Michigan. Sludges from primary and secondary treatment, and skimmings from tertiary treatment are burned in a fluidized bed incinerator along with tank cleaning sludges and other hydrocarbon wastes, including selective noxious refinery waste streams such as spent caustics. The fluidized bed incinerator was designed and built to also dispose of the oily sludge (sulfonate soap). Once-through cooling water is completely segregated with its own collection system, gravity separator, and outfall (EPA application file 1973).

4. UNION CARBIDE

4.1 Introduction

There are three facilities operated by Union Carbide within the Calumet Study Area, the Chemicals and Plastics Division in Whiting, the Linde Air Products Division in East Chicago and the Lakeside T-1200 Plant in Gary. The chemicals and plastics division has two outfalls, one to Lake Michigan and the other to the IHC, both of which are cooling water only. Process waste water is pretreated and then sent to the East Chicago Sewage Treatment Plant. Linde Air Products Division has only one outfall to the IHC, consisting of noncontact cooling water and process waste water. The T-1200 plant has one outfall which has a discharge to Lake Michigan similar in composition to the Linde Division outfall (NPDES Applications).

4.2 Chemicals and Plastics Division - Whiting

At the Union Carbide facility in Whiting, refinery gases are processed into various organic compounds. At present, plant processes include power production, an olefin unit, a low-density polyethylene unit and isopropanol manufacturing. Water use is for cooling purposes with a small volume being diverted for process use. All process waste water is diverted to the East Chicago STP.

4.2.1 Wastewater Discharge

A flow of 40-50 million gallons/day is discharged to Lake Michigan through outfall 001 shown in Figure C-1. Table 4.2 in Chapter 4 indicates effluent parameter concentrations and loadings.

Comparisons between ISPCB monthly operating reports and NPDES data indicate reasonable agreement. For the month of April 1973, however, several process line leaks were encountered which increased the effluent concentrations to relatively high levels. Also, data from a ISPCB 24-hr survey conducted June 15 and 16, 1972, indicate much higher levels than those reported by Union Carbide. Table C-3 for that sampling date BOD is 14 mg/ℓ, COD is 26 mg/ℓ and oil, 4.4 mg/ℓ.

Outfall 002 represents cooling water used in the polyethylene unit with a flow of 216,000 gallons/day to the IHC. NPDES data (Table 4.2) indicate BOD and COD loadings in excess of those measured for 001. Comparisons in Table C-3 show recent ISPCB reports with parameter values considerably lower than the earlier NPDES data.

4.2.2 Wastewater Treatment

Outfall 001 consists entirely of noncontact cooling water and receives no treatment. The waste stream is monitored continuously by a total carbon analyzer to detect possible process leakage. Flow to outfall 002 is treated for oil removal and retained in a holding tank before discharge. Daily samples for BOD, COD, oil, suspended solids and pH are collected and analyzed.

4.3 Linde Air Products Division, East Chicago

This facility extracts oxygen, nitrogen and argon from air by means of low temperature fractionating. Power required for the extraction is, in part, supplied by an on-site generating station. Water use at this facility is primarily confined to noncontact cooling for compressors and condensers (NPDES applications).

4.3.1 Wastewater Discharge

There is one outfall discharging to the IHC. Flow is 150,750 gallons/day. Effluent data are given in Table 4.2. A May 1973 ISPCB report agrees with values for suspended solids but not with chromates and oil. Chromates on NPDES are listed as 0.27 mg/ℓ while ISPCB reports indicate a constant 7.7 mg/ℓ value. Oils are nearly three times greater on ISPCB reports at 14 mg/ℓ average as opposed to 5 mg/ℓ in the NPDES application. Stream loading is 13 lb/day suspended solids, 5 lb/day chromates and 8 lb/day oil.

Table C-3

UNION CARBIDE, CHEMICAL & PLASTICS DIVISION EFFLUENT DATA COMPARISON OF NPDES DATA, OPERATING REPORTS AND EFFLUENT SURVEY

Concentrations, mg/ℓ

	OUTFALL 001				OUTFALL 002			
	BOD	COD	SS	OIL	BOD	COD	SS	OIL
NPDES DATA	6.8	13.2	2.4	1.7	14.5	54	11.5	0.9
ISPCB REPORT APRIL, 1973	3	11	19	0	2	6	0	1
ISPCB REPORT MAY, 1973	3	7	2	0	2	3	0	1
U.S. EPA 24-hr SURVEY	14	26	2.1	4.4	-	-	-	-

ALL DATA IN mg/l

4.3.2 Wastewater Treatment

Oil receives the major emphasis in the treatment process. There are a series of four ponds connected by subsurface dikes. These allow oil to collect on the surface and suspended solids to settle out. Floating oil is removed by pumping and solids are dredged. A rag filter is also employed between the third and fourth ponds. Union Carbide plans to construct an enlarged settling basin which will allow total recycle (EPA application file 1973). Completion dates are unknown at present. At that time, the IHC outfall will handle only storm water runoff from roof drains.

4.3.3 T-1200 Plant - Gary

This facility is similar to the Linde plant in processes and water use. There is one outfall to Lake Michigan with a discharge of noncontact cooling water of 100 mgd. This waste stream receives no treatment other than continuous chlorination to inhibit algae growth. Residual chlorine is reported to be 0.08 mg/ℓ (EPA application file 1973).

5. ATLANTIC RICHFIELD COMPANY

5.1 Introduction

The Atlantic-Richfield Company owns and operates a "Class B" crude oil refinery in East Chicago, Indiana, previously owned by Sinclair, Inc. Crude oil is received by pipeline and is processed into numerous organic compounds. Processes utilized include fractionating, reforming, catalytic cracking, alkylation and polymerization. There is one submerged discharge into the Lake George Branch of the Indiana Harbor Canal with a flow of 4.75 mgd, shown in Figure C-2.

Water usage at the facility is for power generation and steam production. Steam is used in many process lines and becomes contaminated with oil and ammonia products. Noncontact cooling water from various lines is combined with process water and treated at the Industrial Waste Treatment Plant. Concentrated ammonia and sanitary wastes are sent to the East Chicago Sewage Treatment Plant (EPA application file 1973).

5.2 Data Evaluation

Data submitted for NPDES evaluation in 1971 was updated in July of 1973. Effluent parameter concentrations are listed in Table 4.2. Values reported for ammonia-nitrogen, Kjeldahl-nitrogen, C.O.C., cyanide, iron, and phenols are relatively high. A report prepared by the U.S. EPA in September 1971 (EPA application file) compares data obtained in a 24-hr effluent survey with the then applicable effluent guidelines. Several parameters exceeded the guidelines including chlorides, sulfates, nitrates, total phosphorus, iron, phenol, cyanide and total dissolved solids. Furthermore, the NPDES application was updated as shown in Table C-4. This table indicates that several of these parameters have increased 1971 to 1973. The 1971 EPA report mentions the projected addition of a coker, fluid catalytic cracker, hydro-cracker and a crude still. Arco is the only industry in the Calumet area whose effluent has not improved but rather has degraded in quality.

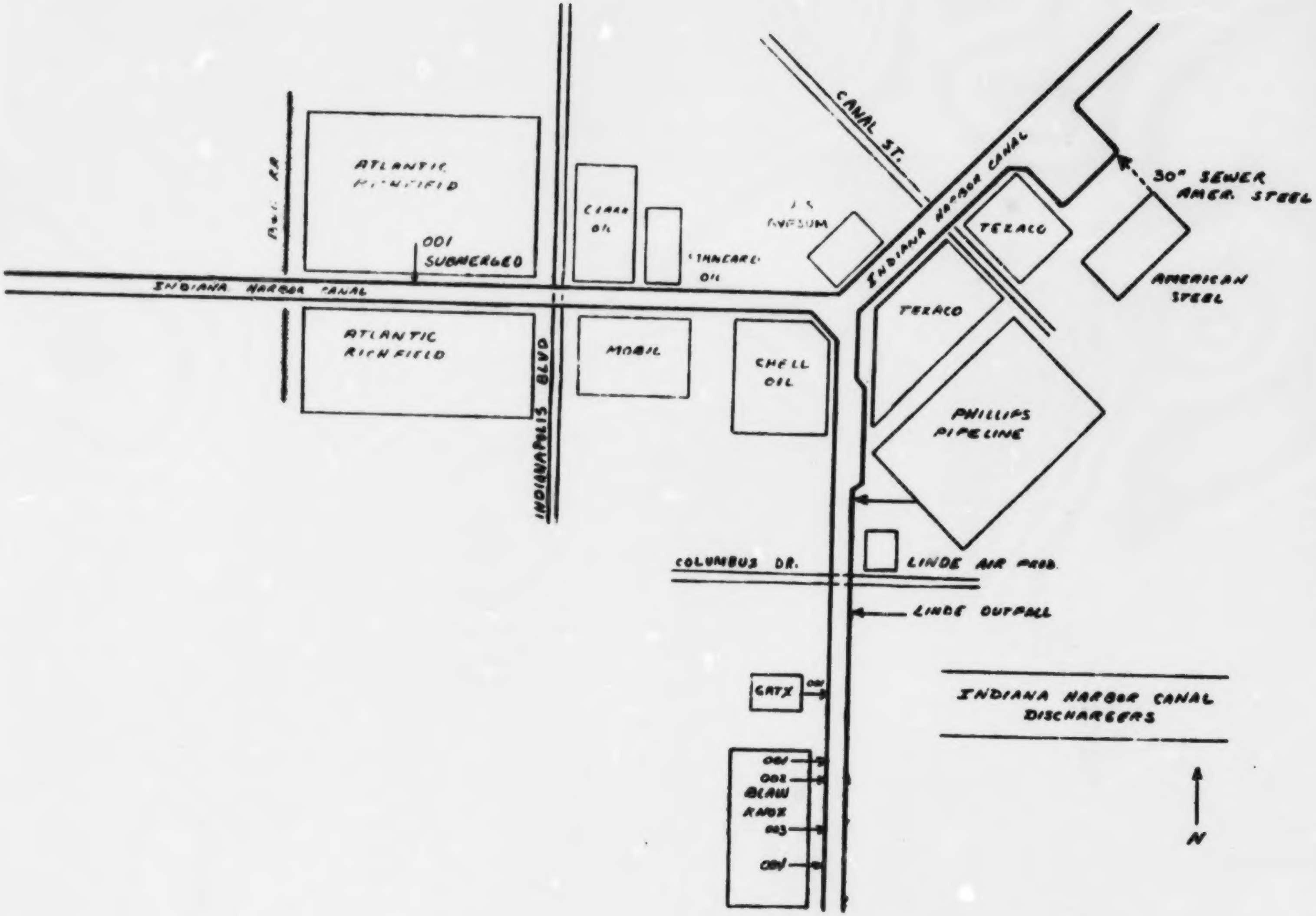

B&O RR
ATLANTIC RICHFIELD
001 SUBMERGED
INDIANA HARBOR CANAL
ATLANTIC RICHFIELD
INDIANAPOLIS BLVD
CLARK OIL
STANDARD OIL
MOBIL
U.S. GYPSUM
SHELL OIL
CANAL ST.
INDIANA HARBOR CANAL
TEXACO
TEXACO
30" SEWER AMER. STEEL
AMERICAN STEEL
PHILLIPS PIPELINE
LINDE AIR PROD.
COLUMBUS DR.
LINDE OUTFALL
GATX
001
001
002
BLAW KNOX
003
001
INDIANA HARBOR CANAL DISCHARGERS
N

Figure C-2

DETAIL MAP OF INDIANA HARBOR CANAL DISCHARGES

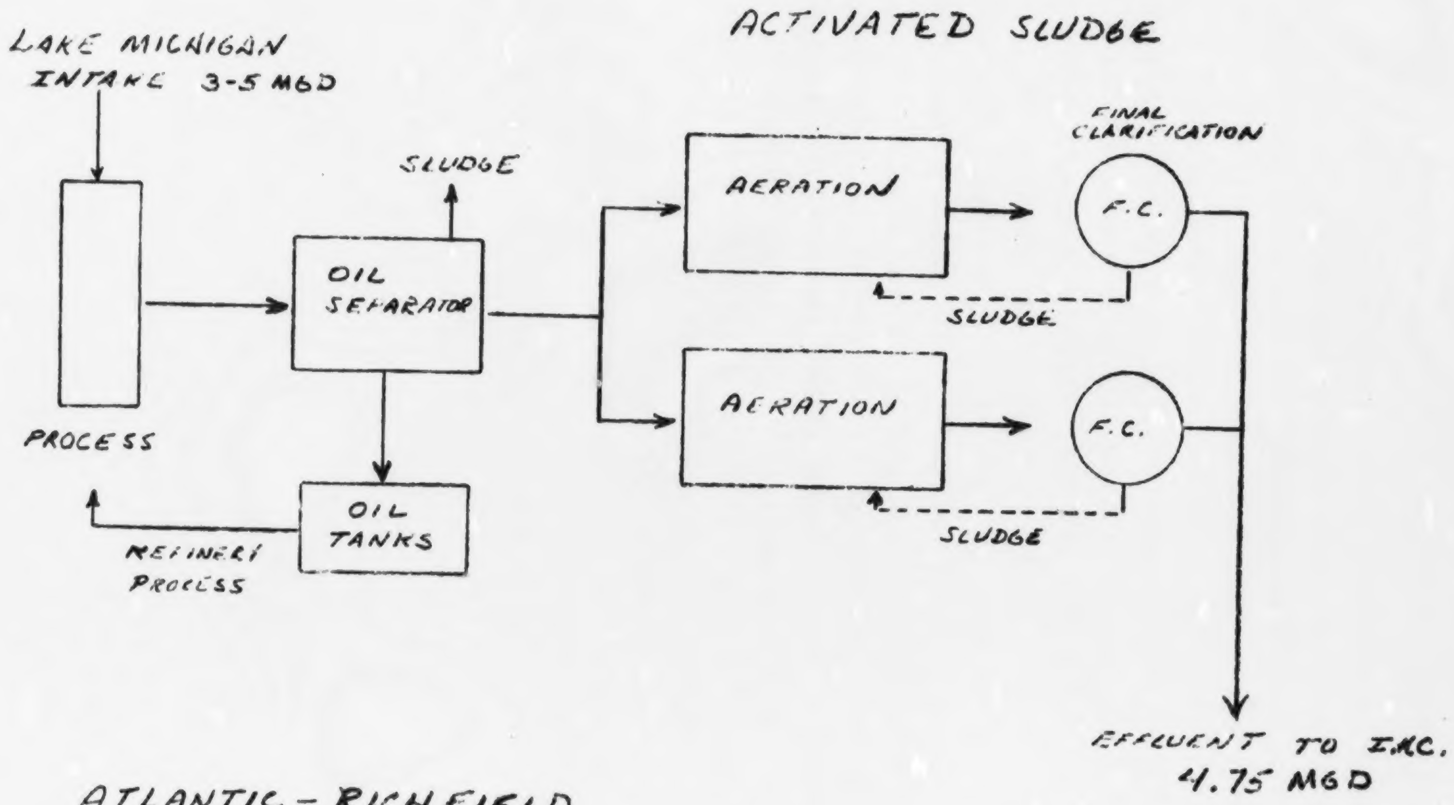
Table C-4

ATLANTIC-RICHFIELD NPDES DATA COMPARISON
PARAMETERS SHOWING INCREASE
Concentrations, mg/ℓ

PARAMETER	NPDES 6/25/71	NPDES 7/16/73
BOD	10	14.3
COD	125	167
TS	965	978
TSS	15	28.6
NH_3-N	10	14.3
Cr	0.15	0.24

5.3 Waste Treatment

The total refinery effluent passes through oil separators where oil is skimmed and sent back through the refinery for processing (Figure C-3). This waste oil is stored in two tanks. Sludge from oil separation, tank bottoms, etc. are stored in tanks before going to a sludge disposal area. After process water passes through the oil separators, it goes to an activated sludge treatment plant. Two activated sludge complete mix tanks, having a capacity of 4,059,000 gallons, provide treatment before final clarification. These tanks provide 34 hr detention at 2,000 gpm, 27 hr at 2,500 gpm, or 19.4 hr at 3,500 gpm. Effluent from the aeration tanks is sent to final clarifiers. Sludge from the final tanks is sent back to the activated sludge mix tanks and excess sludge goes to an aerobic sludge digestion tank, then to a sludge thickener. The thickened sludge is sent to a sludge disposal contractor and the supernatant is recycled through the system. Effluent from the final clarifiers is sent to a manhole, then to a submerged outfall for discharge into the Lake George Branch of the Indiana Harbor Canal (Figure C-2). The total refinery effluent is monitored (by a Beckman 9500 automatic monitor) for flow, temperature, dissolved oxygen and total organic carbon (EPA application file 1973).


ACTIVATED SLUDGE
LAKE MICHIGAN
INTAKE 3-5 MGD
PROCESS
SLUDGE
OIL SEPARATOR
OIL TANKS
REFINERY PROCESS
AERATION
AERATION
FINAL CLARIFICATION
F.C.
F.C.
SLUDGE
SLUDGE
EFFLUENT TO I.H.C.
4.75 MGD

ATLANTIC - RICHFIELD
Waste treatment flowsheet

Figure C-3

6. E. I. DU PONT

6.1 Introduction

The E. I. DuPont de Nemours facility is located on the Grand Calumet River near its junction with the Indiana Harbor Canal in East Chicago. See Figure C-4. The facility produces inorganic industrial chemicals and operates continuously with process waste water and noncontact cooling water discharged to the Grand Calumet River. At present, the plant is in the process of complying with a consent decree issued November 14, 1972, resulting from litigation initiated by the U.S. government.

6.2 Discharges

There are ten reported discharges in the NPDES application of March 17, 1972 (Figure C-5). Outfall 006 has been closed leaving nine outfalls. This number is expected to change as compliance with the Consent Decree is achieved. DuPont is expected to have only three outfalls by December 18, 1973.

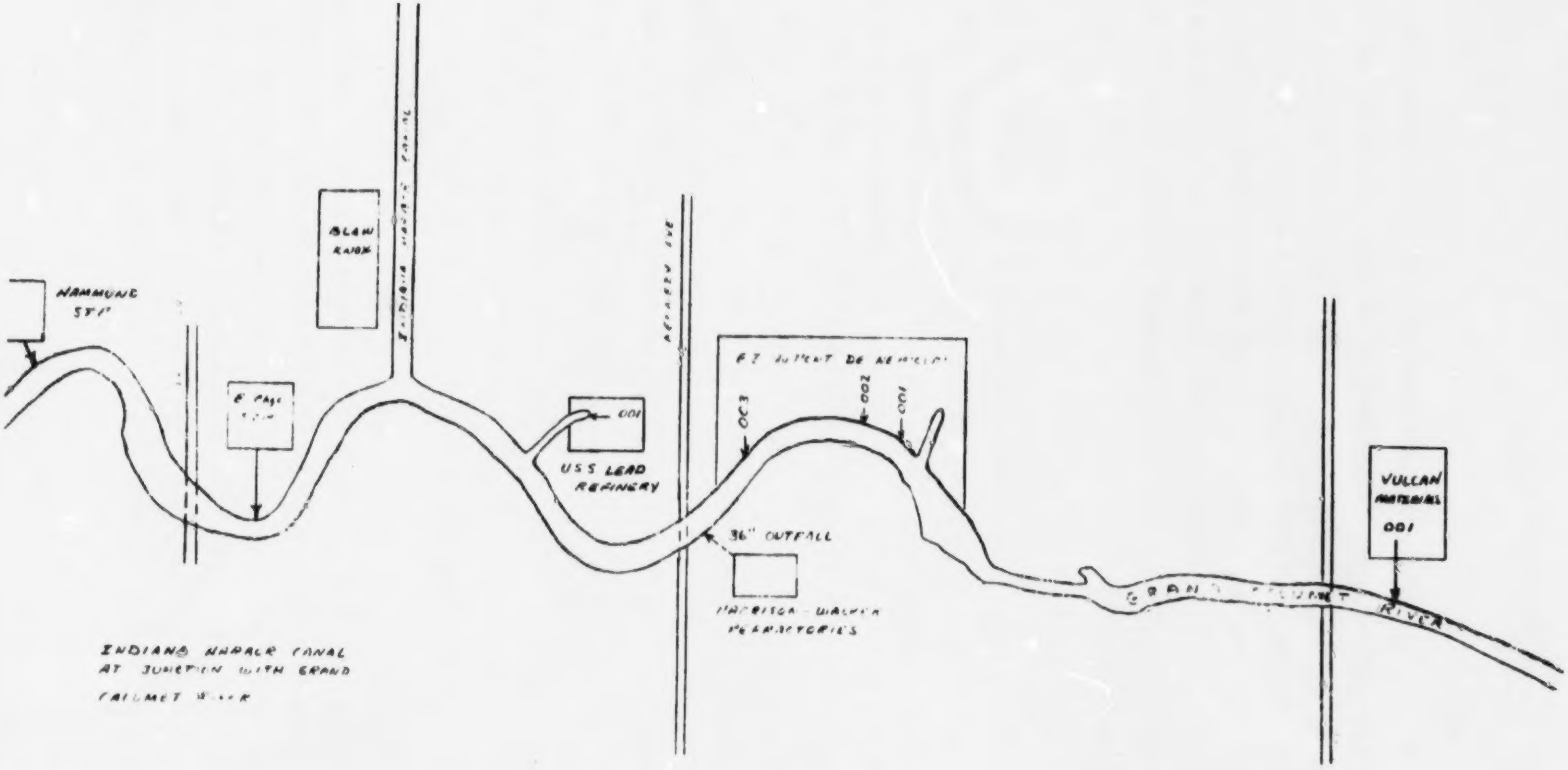
Effluent parameters are given in Table 4.2, even though these will not be representative after December 18, 1973. Since these data will no longer be valid, no attempt is made to cross check the NPDES data with ISPCB monthly operating reports.

6.3 Proposed Effluent Loads

Of the three outfalls remaining after December 18, 1973, 001 will discharge noncontact cooling water with 002 and 003 discharging treated process waste. See Table C-5.

6.4 Waste Treatment

Outfall 002 will contain waste water from the Freon manufacturing area, sulfuric acid manufacturing area, sulfamic manufacturing area and the agricultural manufacturing area. Treatment for this waste stream will consist of various collecting tanks, a neutralization tank, a 46,000 gallon settling tank, and three cartridge filters. Continuous monitoring for various parameters



HAMMOND STP
E Chgo
BLAW KNOX
INDIANA HARBOR CANAL
USS LEAD REFINERY
001
KENNEDY AVE
E I DUPONT DE NEMOURS
003
002
001
36" OUTFALL
HARBISON-WALKER REFRACTORIES
VULCAN MATERIALS
001
GRAND CALUMET RIVER
INDIANA HARBOR CANAL AT JUNCTION WITH GRAND CALUMET RIVER

Figure C-4

DETAIL MAP OF GRAND CALUMET RIVER DISCHARGES

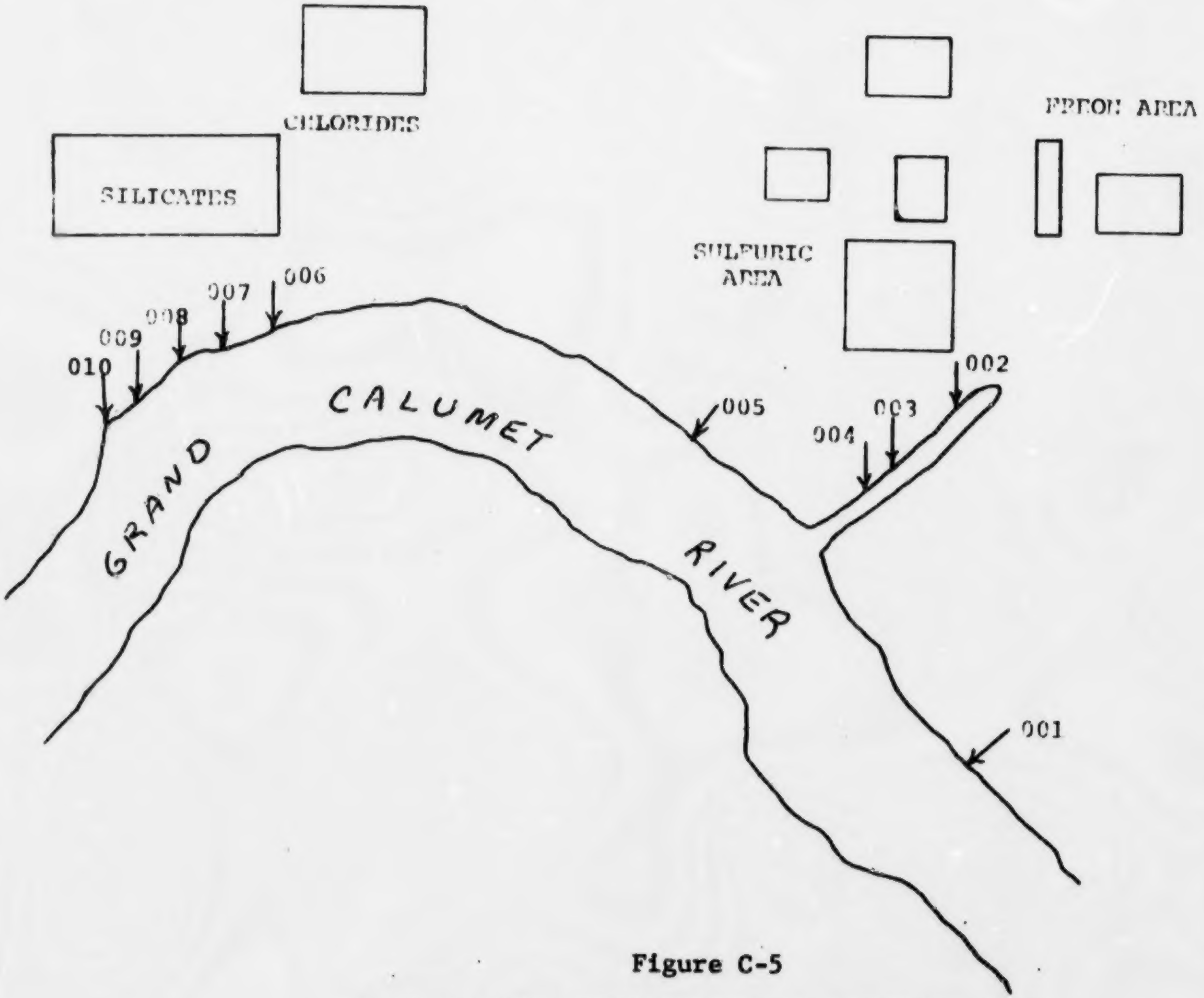

CHLORIDES
SILICATES
FREON AREA
SULFURIC AREA
006
007
008
009
010
005
004
003
002
001
GRAND CALUMET RIVER

Figure C-5

E. I. DU PONT OUTFALLS PRIOR TO DECEMBER 1973

Table C-5

E. I. DU PONT EFFLUENT LOADS

Beginning January 15, 1974 through October 15, 1974, the effluent loads will be:

Parameter	Loading, lb/day	Monthly average
Zn	8	12
P	4	6
Suspended solids	600	900
Chlorides	2500	4800

After October 15, 1974, the loads will be:

Parameter	Loading, lb/day	Monthly average
Sulfates	39,000	58,500
Dissolved solids	74,000	102,000

will be included along with a final pH and adjustment unit. A flow of 1400 gpm is expected.

Outfall 003 will discharge wastes from the chloride and silicate products manufacturing area. Treatment will consist of two 300,000 gallon equalization tanks, a rapid agitation coagulator, a flocculator and thickener followed by two diatomaceous earth coated rotary filters. This flow will then combine with another waste stream from the Ludox area. Combined, the waste flow of 600 gpm will go through two 16-ft high pressure sand filters and receive final pH adjustment before being discharged.

7. BETHLEHEM STEEL

7.1 Introduction

This facility, located at the Burns Waterway Harbor, is the newest in the study area and consequently one of the best in pollution control. The plant was built during the 1960's and $33 million has been expended on air and water pollution abatement equipment with the results being apparent in the effluent concentrations reported in the NPDES application.

7.2 Data Evaluation

The Burns Harbor plant has 163 coke ovens, one blast furnace and two basic oxygen furnaces (300 tons each). Water usage is 28.0 million gallons/day and there are two outfalls, one to the Little Calumet River and the other to the Burns Waterway Harbor. Effluent parameter concentrations are listed in Table 4.2 with outfall location shown in Figure C-6.

The correlation between ISPCB monthly operating reports and the NPDES application for BOD and suspended solids is very good. Data for all other information contained on the NPDES cannot be confirmed since they are not included in the ISPCB monthly reports.

7.3 Waste Treatment

For the coke plant, blast furnace and BOF shop, waste water is given physical-chemical treatment, cooled and then recirculated. Finishing mill waste goes to the main treatment plant where primary treatment removes oil and large particulates. Secondary treatment is physical-chemical with a flocculator and clarifier to remove additional wastes. The effluent from the clarifier passes to a finishing lagoon which is aerated (NPDES Application File).

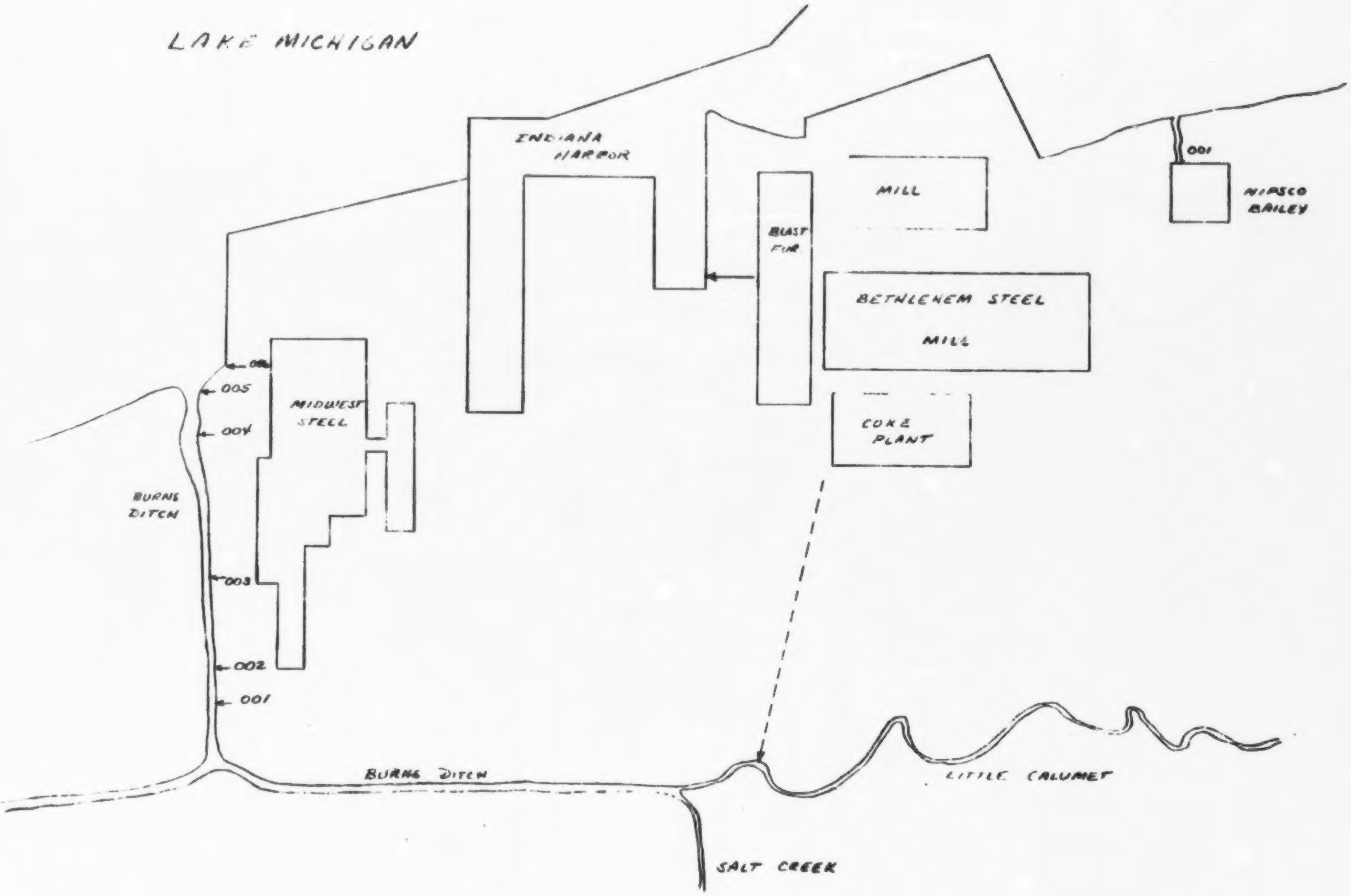

LAKE MICHIGAN
INDIANA HARBOR
MILL
BLAST FUR
BETHLEHEM STEEL
MILL
COKE PLANT
001
NIPSCO BAILEY
006
005
004
003
002
001
MIDWEST STEEL
BURNS DITCH
BURNS DITCH
LITTLE CALUMET
SALT CREEK

Figure C-6

DETAIL MAP OF BURNS DITCH DISCHARGES

8. MIDWEST STEEL - PORTAGE

8.1 Introduction

Midwest Steel is a division of National Steel Co., which is the fourth largest steel producer in the nation. The Midwest facility in Portage, Indiana, is a finishing mill only and does not conduct coke, blast furnace or basic oxygen operations. Cold reduction, sheet tempering, annealing and plating operations are performed.

There are six outfalls from Midwest into Burns Ditch. See Figure C-6. For five of these, NPDES applications have been submitted. Outfall 006 is a discharge from a privately owned sewage treatment plant and has no NPDES application.

8.2 Data Evaluation

Outfalls 001, 002, 003, 005 are all noncontact cooling water from air compressors and oil coolers. Storm water run-off from roof drains is also included in these outfalls. Effluent flows, concentrations and loads are given in Table 4.2.

Outfall 004 represents the discharge from the Industrial Waste Water Treatment Plant. Wastes from the continuous pickle line, cold reduction mill, cleaning line, sheet tempering, annealing, plating preparation, electroplating, hot dip zinc coating lines and boiler blow-down lines are channeled into the industrial treatment plant where physical-chemical treatment occurs.

Comparisons given in Table C-5 between NPDES and ISPCB data indicate close correlation for those parameters listed.

Data for outfall 006 are available only from ISPCB monthly operating reports and EPA 24-hr surveys (Table C-6). Average flow is approximately 10,000 gpd with BOD and suspended solids values very low at 2 and 7 mg/ℓ, respectively. Discharge is to Burns Ditch. No NH_3-N values were given for this outfall.

Table C-6

MIDWEST STEEL EFFLUENT DATA
COMPARISON OF NPDES WITH MONTHLY OPERATING REPORTS TO ISPCB AND U.S. EPA SURVEY

Concentrations, mg/ℓ except for turbidity, JTU

OUTFALL #004

Flow 9.06 mgd

	BOD	TURBIDITY	SULFATE	CYANIDE	CHROMIUM	IRON	OIL
NPDES	3.1	25	375	0.05	0.03	0.5	2.0
ISPCB REPORT APRIL, 1973	3.7	25	434	0.10	0.02	0.3	3.0
ISPCB REPORT MAY, 1973	3.2	25	555	0.11	0.04	0.5	1.9

OUTFALL 006

FLOW [illegible]00 GPD

Concentrations, mg/ℓ

	BOD	SUSPENDED SOLIDS	RES. CHLORINE
U.S. EPA 24hr SURVEY	2	20	-
ISPCB REPORT APRIL, 1973	1.2	6.5	0.17
ISPCB REPORT MAY, 1973	2	7.7	0.14

8.3 Waste Treatment

Midwest's facility, being constructed in the 1960's, was able to incorporate some of the latest technology available for pollution control.

9. INLAND STEEL COMPANY

9.1 Introduction

The Inland Steel facility in East Chicago, Indiana, is one of the largest steel mills in the country producing 5.3% of the nation's total steel output. There are 523 coke ovens, 19 open hearth furnaces (12 of which are due to close), 2 basic oxygen and 2 electric furnaces. Water use is 1,008 mgd discharged through 15 outfalls shown in Figure C-7. Processes utilizing water include coke quenching, coke processing, ironmaking, steelmaking, sintering and hot and cold rolling (Council on Economic Priorities 1973).

9.2 Data Evaluation

Of the 18 outfalls included in the NPDES application, three 008, 009, and 010, have been discontinued. See Table C-7. The remaining outfalls and their effluent parameter concentrations are listed in Tables 4.2 and C-8. The concentrations reported in 1971 reflect the completion of an extensive waste water treatment program at Inland. Since late 1970, no major additional treatment has been placed on line.

A comparison between NPDES data and a recent 24-hr survey conducted by the Indiana Stream Pollution Control Board is given in Table C-9. Data obtained during the survey agrees closely with that submitted in the NPDES application. The only exceptions are the values for total iron. These values fluctuate widely, being either substantially more or less than NPDES values.

Comparison with ISPCB monthly operating reports in Table C-10 again show fluctuations in iron values with relatively stable values for other parameters. The ISPCB monthly operating reports for April and May of 1973 (Table C-10) indicate a high degree of dependence upon intake water loading conditions in determining the total effluent quality.

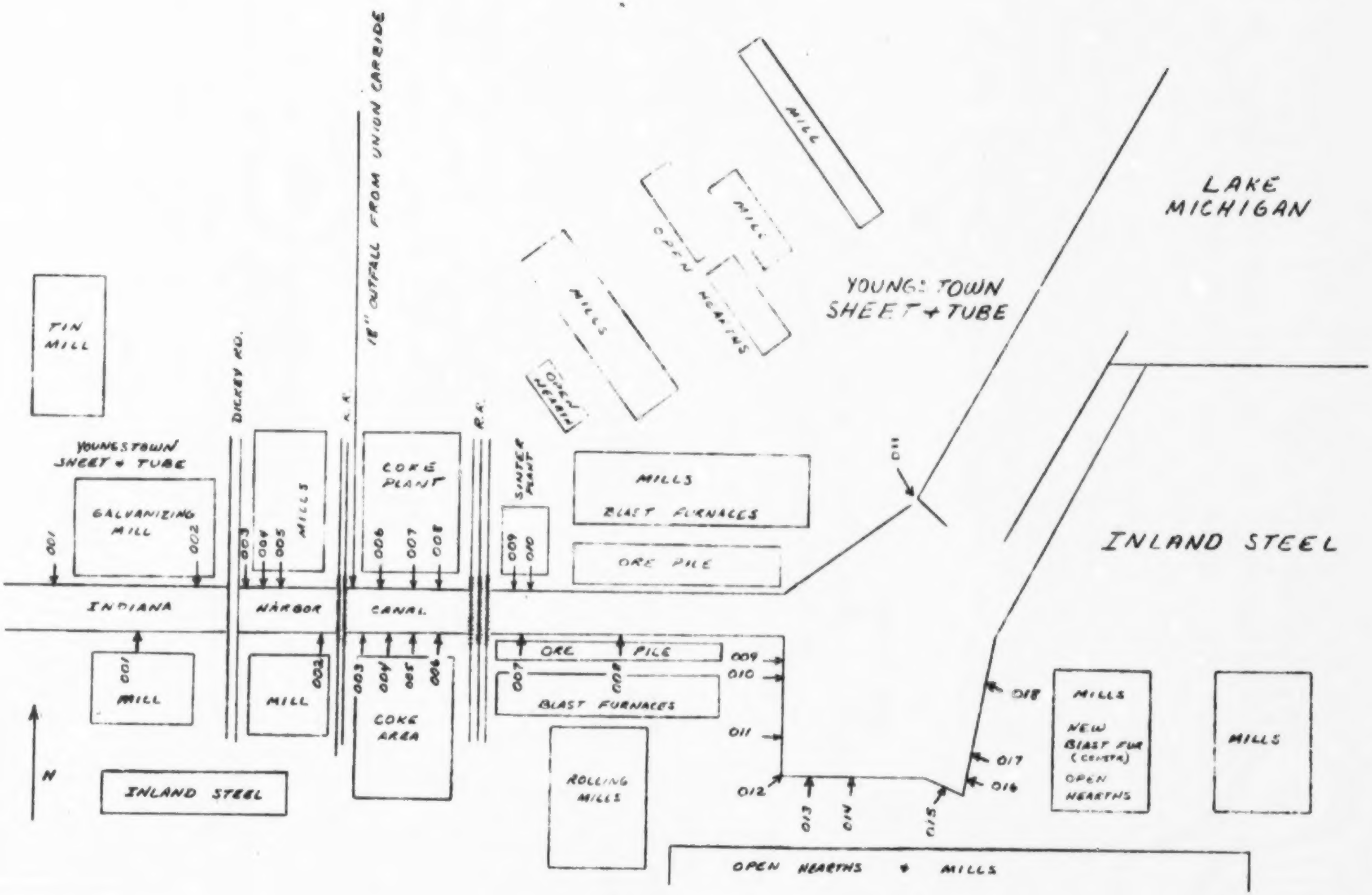

LAKE MICHIGAN
YOUNGSTOWN SHEET + TUBE
INLAND STEEL
MILL
MILLS
OPEN HEARTHS
MILLS
OPEN HEARTH
TIN MILL
YOUNGSTOWN SHEET + TUBE
GALVANIZING MILL
DICKEY RD.
R.R.
18" OUTFALL FROM UNION CARBIDE
COKE PLANT
R.R.
SINTER PLANT
MILLS
BLAST FURNACES
ORE PILE
001
002
003
004
005
006
007
008
009
010
011
INDIANA
HARBOR
CANAL
001
MILL
002
MILL
003
004
005
006
COKE AREA
ORE PILE
007
008
BLAST FURNACES
ROLLING MILLS
009
010
011
012
013
014
015
016
017
018
MILLS
NEW BLAST FUR (CONSTR)
OPEN HEARTHS
MILLS
N
INLAND STEEL
OPEN HEARTHS + MILLS

Figure C-7

DETAIL MAP SHOWING OUTFALLS FROM INLAND AND YOUNGSTOWN STEEL COS.

Table C-7

INLAND STEEL COMPANY OUTFALL SUMMARY
Source: NPDES APPLICATION

Outfall number		Flow, mgd	Average pH	Average temperature	
NPDES	ISPCB			Winter	Summer
001	01E-2	0.144	8.2	34	68
002	4E-1	190	7.9	45	80
003	5E-1	7.225	7.9	45	77
004	5E-2	0.864	8.0	46	80
005	5E-3	8.64	8.1	59	93
006	6E-1	0.648	8.3	46	80
007	7E-1	21.6	7.5	55	89
~~008~~		-	-	-	-
009	13F-1	-	-	-	-
010	13F-2	-	-	-	-
011	13G-1	158.7	8.0	48	82
012	13H-1	84.6	8.0	56	90
013	14H-1	106.9	8.0	45	79
014	15H-1	106.9	8.0	45	79
015	16H-1	21.6	8.2	54	88
016	16H-2	12.9			
017	16H-3	144			
018	16F-1	149.7			
New proposed	24K-1	0.14			
outfalls	24N-1	50.4			

Inland Steel
IN 070 OX3 2 720129

Table C-8

INLAND STEEL COMPANY EFFLUENT CONCENTRATIONS

Application Date: June 22, 1971
mg/l, except * = ug/l

OUTFALLS	ALKALINITY	BOD	COD	TOTAL SOLIDS	TOTAL DISSOLVED SOLIDS	TOTAL SUSPENDED SOLIDS	TOTAL VOLATILE SOLIDS	AMMONIA	KJELDAHL NITROGEN	NITRATE	PHOSPHORUS, TOTAL	COLOR	TURBIDITY	TOTAL HARDNESS	SULFATE	SULFIDE	CHLORIDE	CYANIDE	FLUORIDE	ALUMINUM*	ANTIMONY	ARSENIC*	CADMIUM	CALCIUM	CHROMIUM*	COPPER*	IRON*	LEAD*	MAGNESIUM	MERCURY	NICKEL*	POTASSIUM	SODIUM	TIN	ZINC*	OIL AND GREASE	PHENOLS*
001	92	3	11	308	296	13	43	.12	.46	.33	.03	33	19	264	480	0	26	0	.18	221	0	3	0	45.2	12	13	1150	22	12	0	12	2.2	10	0	28	7	0
002	112	2	1	158	150	17	44	0.59	0.64	0.19	0.03	13	15	150	20	.2	18	.59	.14	-	0	3	0	18.4	4	16	[illegible]	12	10	0	9	2.6	6	0	82	2	8
003	106	2	11	227	207	23	13	.19	83	16	.01	15	7	146	25	0.0	41	0	.13	-	0	4	0	-	0	25	2450	20	-	0	10	2.10	16	0	20	9	0
004	110	2	11	176	150	22	27	.17	23	13	.01	20	8	146	23	0.0	12	0	.06	-	0	4	0	-	2	40	1786	80	-	0	12	1.5	5	0	19	9	0
005	100	14	9	173	145	25	38	0.23	0.58	0.35	0.02	20	18	158	26	0.1	11	0	8	-	0	6	0	-	1	47	2175	86	-	0	14	1.5	5	0	31	18	0
006	115	3	11	257	249	8	97	.39	1.09	.45	.02	20	10	186	54	0	25	0	.29	-	0	2	0	55.2	0	5	200	0	-	0	0	5.6	17	0	13	3	0
007	108	1	8	150	144	16	40	.17	.70	.27	.01	13	14	144	26	.2	12	.56	.02	-	0	5	0	-	0	7	675	19	-	0	9	1.70	5	0	181	3	35
011	108	2	4	159	133	13	37	.18	.55	.28	.02	10	14	144	25	.1	13	.09	.13	-	0	4	0	38.8	9	11	237	21	-	0	17	1.7	7	0	171	2	8
012	109	2	6	253	245	18	15	3.42	1.25	0.4	.01	55	9	164	26	.1	38	.13	.34	-	0	6	0	41.6	4	6	340	15	-	0	10	5.5	7	0	633	2	180
013	106	9	22	224	201	18	81	1.41	3.50	.23	.01	48	29	152	30	.1	25	.12	.16	-	0	6	0	-	4	17	4000	13	-	0	14	2.0	6	0	25	5	192
014	107	9	24	188	175	19	15	1.23	3.44	.36	.01	36	19	149	30	0.1	25	.12	.08	-	0	9	0	-	1	12	3800	18	-	0	20	2.0	6	0	29	5	191
015	110	2	10	175	171	3	25	.14	.36	.17	.05	13	7	144	24	.1	14	0	.12	-	0	6	0	-	0	16	209	0	-	0	17	2.2	9	0	12	7	0
016	111	2	12	200	187	19	30	.23	.45	1.10	.11	9	10	145	25	.1	14	0	.14	-	0	2	0	-	0	18	190	0	-	0	5	2.2	9	0	14	4	0
017	111	6	16	189	172	17	49	.17	.21	.11	.01	16	11	149	24	.1	12	0	8	-	0	7	0	-	4	4	737	0	-	0	3	1.5	5	0	12	4	0
018	112	2	13	214	201	21	34	.15	.33	.33	.03	17	12	157	29	0	11	0	.16	-	0	3	0	43.6	4	15	1880	65	-	0	5	1.8	6	0	78	2	0

Table C-9

INLAND STEEL EFFLUENT CONCENTRATIONS
COMPARISON OF NPDES AND ISPCB 24-HR SAMPLES JULY

Parameters in mg/ℓ except * = μg/ℓ

OUTFALL#	001		002		003		004		005	
SOURCE	NPDES	ISPCB	NPDES	ISPCB	NPDES	ISPCB	NPDES	ISPCB	NPDES	IS
BOD	3.0	3.3	2.0	1.0	2.0	1.8	2.0	1.5	14.0	1.8
TS	308	320	158	180	227	270	176	280	173	220
NH_3-N	.12	.3	.59	.3	.19	.1	.17	.1	.23	.13
TOT. P	.3	1.2	.03	.04	.1	.1	.01	.04	.02	.06
TOT. Fe	1.2	1.0	.23	.4	2.5	1.1	1.8	6.5	2.2	0.8
OIL	7	-	2	-	9	-	9	-	18	-
PHENOL*	0	-	8	-	0	-	0	-	0	-

	007		011		012		013		014	
BOD	1.0	1.0	2.0	1.0	2.0	1.6	9.0	2.3	9.0	1.8
TS	150	160	159	190	253	330	224	210	188	210
NH_3-N	.17	.3	.18	.2	3.42	.4	1.41	.2	1.23	.2
TOT. P	.01	.03	.01	.06	.01	.03	.01	.03	.01	.03
TOT Fe	.7	.6	.2	.5	.3	.3	4.0	2.6	3.8	2.2
OIL	3	-	2	-	2	-	5	-	5	-
PHENOL*	35	-	8	-	100	-	192	-	191	-

OUTFALL #	015		016		017		018	
SOURCE	NPDES	ISPCB	NPDES	ISPCB	NPDES	ISPCB	NPDES	ISPCB
BOD	2.0	2.1	2.0	2.2	4.0	3.5	2.0	1.9
TS	175	230	200	190	189	200	214	210
NH_3-N	.14	.1	.23	.2	.17	.1	.15	.2
TOT. P	.05	.15	.11	.30	.01	.03	.03	.05
TOT. Fe	.2	.3	.2	.5	.7	.8	1.8	.8
OIL	7	-	4	-	4	-	2	-
PHENOL*	0	-	0	-	0	-	0	-

Table C-10

INLAND STEEL MONTHLY OPERATING REPORT DATA
APRIL, 1973 MAY, 1973
Concentrations in mg/ℓ except * = μg/ℓ

OUTFALL	001		002		003		004		005		006		007		011		012		013		014		016*		017		018	
MONTH	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY	APR	MAY
BOD																			7	6	8	6						
COD																			26	29	22	18						
PHENOL*	15	9																	42	36	56	34						
CYANIDE																			.04	.63	.34	.03						
OIL	3	3	2	3	9	5	12	5	18	17			1	1	1	1	2	2	3	4	4	4	1		3	5	1	1
SS	25	15	27	11	29	10	30	21	34	19			30	11	30	[illegible]	25	17	35	26	27	17	12		28	21	21	15
SULFATE			33	27															33	27	32	28						
NH_3-N			.78	.58															.62	.65	.41	.63						
TOT. Fe																			3.7	4.1	2.5	2.8						
CHLORIDE			16	16	57		11												17	13	19	18						

9.3 Waste Treatment

The last major program for wastewater treatment ended in 1970 with the completion of a $10 million "terminal treatment plant" which consolidated the flow from six outfalls. This treatment facility receives effluents from numerous finishing operations, the sinter plant and the open hearth shop. Treatment consists of primary settling basins, oil skimmers and a 1000-ft terminal settling basin (Figure C-8).

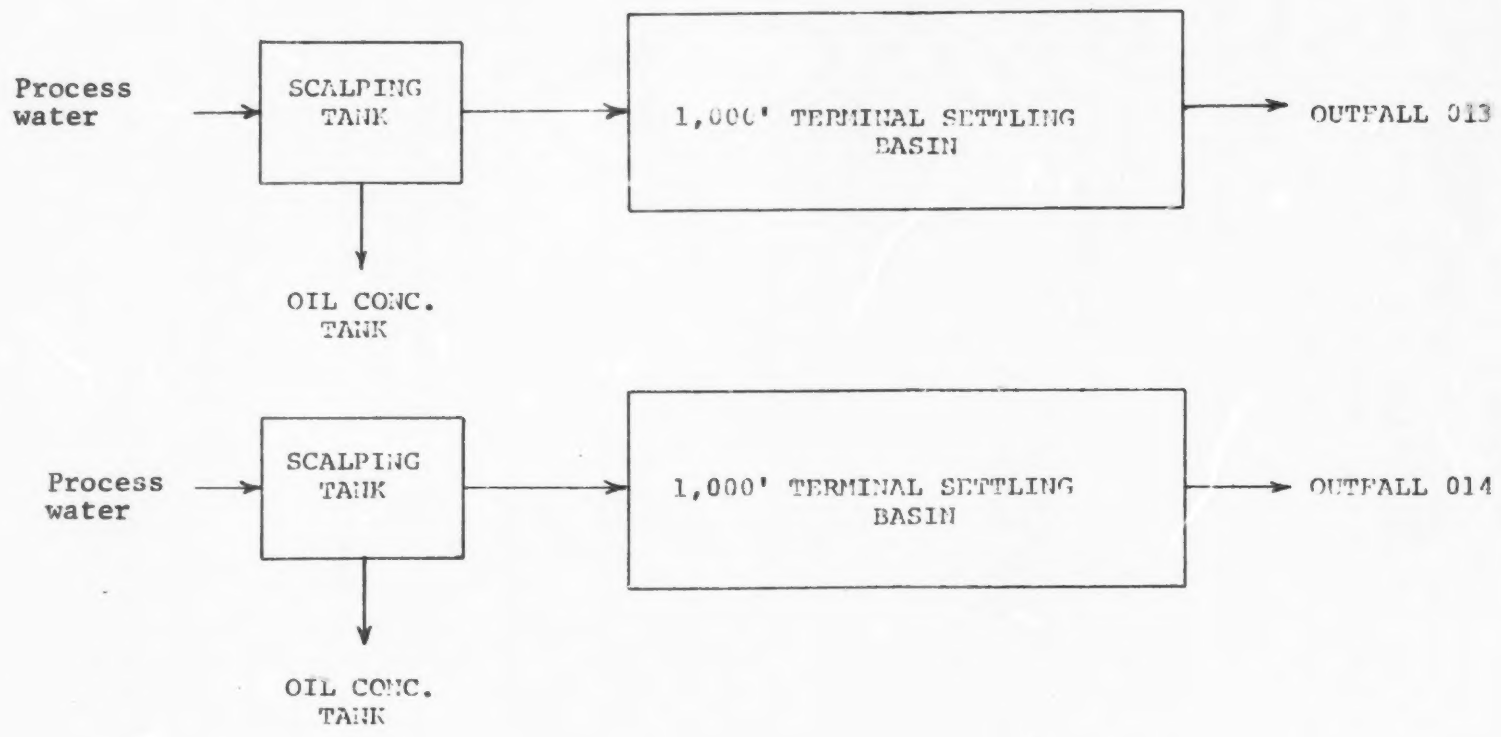
Other waste streams receiving treatment as part of this most recent phase include the 80-in. cold strip mill, blast furnace waste, electric furnace and biller caster shops. Waste from the basic oxygen furnace and the 12-in. merchant bar mill are treated and recirculated. Acid pickle liquor is now being discharged into a deep well (4300 ft) at a rate of 164,000 gpd.

Prior to 1965, many additional plant processes received treatment systems. What remains now are fifteen active discharges with total net parameter loads shown in Figure 4.2. Although individual effluent streams may not contain excessive amounts of pollutants, the total volume of water discharged daily (1008.9 mgd) indicates a large pound loading of pollutants reaching Lake Michigan. Phenols average 440 lb/day and NH_3-N average 5536 lb/day.

A citizen complaint against Inland filed before the Stream Pollution Control Board has resulted in an eight-point program of pollution control. Plans include additional treatment for outfalls 003, 004 and 005, plant #2 and #3 blast furnace wastes, and acid pickle liquor line improvements. Further action and approval by the Indiana Stream Pollution Control Board is expected. In addition, an Illinois lawsuit (People of the State of Illinois vs Inland Steel Co. 1974) has resulted in a finding that Inland Steel Co. is polluting Illinois waters of Lake Michigan, and the parties have been ordered to negotiate corrective action.

Figure C-8

INLAND STEEL COMPANY TERMINAL WASTE TREATMENT


Process water
SCALPING TANK
1,000' TERMINAL SETTLING BASIN
OUTFALL 013
OIL CONC. TANK
Process water
SCALPING TANK
1,000' TERMINAL SETTLING BASIN
OUTFALL 014
OIL CONC. TANK

10. YOUNGSTOWN SHEET AND TUBE CO., EAST CHICAGO

10.1 General Description

The Youngstown Sheet and Tube Co. Indiana Harbor Works is an integrated steel producing facility located adjacent to the Indiana Harbor Canal and Lake Michigan in East Chicago, Indiana. This facility includes coke ovens, blast furnaces, open hearth and BOF processes, primary and secondary mills for the production of sheet, galvanized tin, bar, plate and tube products. In 1971, 7906 tons of steel were produced daily. Water discharges from cooling and process lines total 291 mgd from 11 outfalls (Council on Economic Priorities 1973).

10.2 Data Evaluation

There are 11 outfalls which discharge directly to the IHC. The discharges are shown in Figure C-7. Flow from these outfalls averaged 291.67 mgd at the time of filing the NPDES permit in June 1971. Present flow and process line information is provided in Table C-11. Most existing treatment facilities were completed by late 1970. Permit data in Tables 4.2 and C-12 should therefore be an accurate portrayal of existing conditions.

Data comparisons between NPDES, ISPCB 24-hr surveys and monthly operating reports are of limited value since all parameters for all outfalls are not given. Available data are compared in Table C-13.

The most dramatic differences occur between reported values on the NPDES and those values obtained in a 24-hr composite sampling conducted by the Indiana Stream Pollution Control Board on June 13 and 14, 1972. These data indicate values in excess of those reported in the NPDES for suspended solids, iron, and phosphorus. Iron content was exceptionally high for outfalls 004 and 005 with values of 90 and 45 mg/ℓ, respectively.

Table C-11

YOUNGSTOWN SHEET & TUBE COMPANY
NPDES AND ISPCB OUTFALL IDENTIFICATION AND FLOWS

JULY 1973

OUTFALLS			
NPDES	ISPCB	FLOW-MGD	PROCESS LINE
001	20	15.2	Central Waste Treatment Plant
002	2	2.3	Cold Reduced Sheet Mill
003	4	.079	#1 Tin Mill
004	8	1.298	#1 Tin Mill
005	11	2.24	#1 Tin Mill
006	12	6.26	Coke Plant
007	13	14.6	Coke Plant
008	22	9.53	Coke Plant
009	14	50.9	Sinter Plant
010	15		Blast Furnace Cooling Water
011	18A	65.0	Sinter Plant

Monthly operating reports submitted by the company have little information for some outfalls and none for others. An accurate and reliable picture of present effluent discharges is difficult to assess for the parameters of suspended solids, iron, and phosphorus. Ammonia nitrogen, phenols and oil values appear to be consistent between NPDES and monthly operating reports data.

10.3 Waste Treatment

Process water from the cold reduced sheet and tin mills is routed through the Central Waste Treatment Plant (CWTP) consisting of primary mixing tanks, scalping tanks, secondary mixing tanks, final clarifiers and sludge thickeners. The primary purpose is to remove oil and solids in the waste stream. At present there is an emergency by-pass around the CWTP which would discharge untreated wastes into the IHC. After treatment the values (in Table C-13) for iron, oil and suspended solids are still high. They are 5, 8 and 40 mg/ℓ, respectively. Youngstown monitors this effluent daily but does not analyze for phenols, iron, and ammonia nitrogen. After treatment, the effluent is combined with noncontact cooling water from the temper mill of the No. 2 tin mill, and discharged through outfall 001.

Flow of 3.62 mgd of once-through noncontact cooling waters from the No. 2 cold reduced sheet mill is discharged without treatment through outfall 002. Outfalls 003, 004, and 005 are all storm water and noncontact cooling water from electrolytic cooling, forming and pickling line discharges and receive no treatment. Again, these are not monitored.

Youngstown Steel and Tube Company
IN 070 0X3 2 720319

Table C-12

YOUNGSTOWN SHEET AND TUBE COMPANY
Application Date: July 1, 1971
EFFLUENT CONCENTRATIONS
mg/ℓ except * = g/ℓ

OUTFALL#	ALKALINITY	BOD	COD	TOTAL SOLIDS	TOTAL DISSOLVED SOLIDS	TOTAL SUSPENDED SOLIDS	TOTAL VOLATILE SOLIDS	AMMONIA	KJELDAHL NITROGEN	NITRATE	PHOSPHORUS TOTAL	COLOR	TURBIDITY	TOTAL HARDNESS	SULFATE	CHLORIDE	CYANIDE	FLOURIDE	IRON *	POTASSIUM	CHROMIUM*	SODIUM	TIN*	ZINC*	OIL AND GREASE*	PHENOLS*
001	93	5.5	82	614	596	40	8	2	2	.24	.009	65	-	235	620	-	.01	.76	5000	-	-	19	-	-	8	-
002	112	1.5	8	199	194	19	3	2	4	.24	.016	-	5												12	
003	114	1.8	12	200	193	17	4	2	3	.24	.024		9	167	16.4	28		.58					2.5		113	
004	110	5.4	8	219	205	22	6	2	3	.23	.022	88	13		290				5750						10	
005	62	2.6	4	262	244	26	11	3	3	.34	.006	125	39	170	37				9700						11	
006	132	10.4	85	220	213	19	4	31	7	.24	.048		4		30	112	28.8								14	2090
007	108	3.1	36	217	202	20	12	2	3	.24	.028		6		14	37	.04								8	303
008	110	27.8	53	218	198	22	10	4	3	.23	.031	45	6		13.7	29									14	290
009	106	3.4	12	216	200	22	5	2	4	.26	.052		5													
010	110	3.5	24	227	199	107	9	2	3	.25	.041		7							3.75					6.4	
011	132	1.6	8	310	283	22	7	3	3	.19	.028	22	17	235	21.8	21	.17	.75	8550	10.50	13	22		13	10	11

Table C-13

YOUNGSTOWN SHEET & TUBE EFFLUENT DATA, mg/ℓ
COMPARISON OF NPDES, MONTHLY OPERATING REPORTS AND EFFLUENT SURVEYS

Parameter, mg/ℓ	NPDES	ISPCB 24-hr survey 6/13/72	Monthly operating report March 1973	Monthly operating report April 1973	NPDES	ISPCB 24-hr survey 6/13/72	Monthly operating report March 1973	Monthly operating report April 1973
	Outfall 001				Outfall 002			
Chloride	-	-	-	-	-	-	-	-
Sulfate	62.0	-	-	-	-	-	-	-
Ammonia-Nitrogen	2.0	1.0	-	-	2.0	0.8	-	-
Phosphorus	0.009	0.3	-	-	0.016	0.6	-	-
Iron	5.0	2.1	-	-	-	1.3	-	-
Oil and grease	8.0	4.0	5.0	4.0	12.0	3.1	-	-
Phenols	-	0.01	-	-	-	0.001	-	-
Suspended solids	40.0	15.0	12.0	11.0	19.0	97.0	-	-
	Outfall 003				Outfall 004			
Chloride	28.0	-	-	-	-	-	-	-
Sulfate	16.4	-	-	-	290.0	-	-	-
Ammonia-Nitrogen	2.0	-	-	-	2.0	1.1	-	-
Phosphorus	0.024	-	-	-	0.022	0.4	-	-
Iron	-	-	-	-	5.750	90.0	-	-
Oil and grease	1.13.0	-	-	-	10.0	4.8	-	-
Phenols	-	-	-	-	-	0.001	-	-
Suspended solids	17.0	-	-	-	22.0	270.00	-	-
	Outfall 005				Outfall 006			
Chloride	-	-	-	-	112.0	-	-	-
Sulfate	37.0	-	-	-	30.0	-	-	-
Ammonia-Nitrogen	3.0	2.6	-	-	31.0	9.0	15.0	5.0
Phosphorus	0.006	0.4	-	-	0.048	0.4	-	-
Iron	9.70	45.0	-	-	-	1.8	-	-
Oil and grease	11.0	6.9	-	-	14.0	3.6	12.0	5.0
Phenols	-	0.004	-	-	2.09	1.72	1.63	1.10
Suspended solids	26.0	13.0	-	-	19.0	100.0	42.0	4.0

Table C-13 (cont.)

Parameter, mg/ℓ	NPDES	ISPCB 24-hr survey 6/13/73	Monthly operating report March 1973	Monthly operating report April 1973	NPDES	ISPCB 24-hr survey 6/13/73	Monthly operating report March 1973	Monthly operating report April 1973
	Outfall 007				Outfall 008			
Chloride	37.0	-	-	-	29.0	-	-	-
Sulfate	14.0	-	-	-	13.7	-	-	-
Ammonia-Nitrogen	2.0	-	-	-	4.0	-	-	-
Phosphorus	0.028	-	-	-	0.031	-	-	-
Iron	-	-	-	-	-	-	-	-
Oil and grease	8.0	3.4	-	-	14.0	-	14.0	6.0
Phenols	0.303	-	-	-	0.29	-	-	-
Suspended solids	20.0	3.0	-	-	22.0	-	15.0	0
	Outfall 009				Outfall 010			
Chloride	-	-	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-	-	-
Ammonia-Nitrogen	2.0	-	-	-	2.0	-	-	-
Phosphorus	0.052	-	-	-	0.041	-	-	-
Iron	-	-	-	-	-	-	-	-
Oil and grease	-	2.8	-	-	6.4	4.5	-	-
Phenols	-	0.003	-	-	-	0.017	-	-
Suspended solids	22.0	72.0	5.0	0	107.0	85.0	17.0	13.0
	Outfall 011							
Chloride	21.0	-	-	-				
Sulfate	21.8	-	-	-				
Ammonia-Nitrogen	3.0	2.2	-	-				
Phosphorus	0.028	0.2	-	-				
Iron	8.550	2.8	-	-				
Oil and grease	10.0	2.4	-	-				
Phenols	11.0	0.072	-	-				
Suspended solids	22.0	13.0	-	-				

Outfalls 003, 004 and 005 convey untreated cooling water and storm water from the No. 1 tin mill including the electrolytic cooling, forming and pickling lines. Process wastes from these lines are diverted to the CWTP. Although this stream is designated as noncontact cooling water, reported effluent values are very high for iron, phenols and oil (see Table C-12) indicating some contamination. Outfalls 006, 007, and 008 are represented as once-through noncontact cooling waters from the ammonia processing and light oil areas of the coke plant; however, outfall 006 has 31 mg/ℓ of NH_3-N, 14 mg/ℓ of oil and grease, and 2.09 mg/ℓ of phenols. Outfalls 007 and 008 have values of 8 and 14 mg/ℓ of oil and grease. Monthly reporting for 006 includes NH_3-N phenols and oil, while no reporting is done for 007. Outfall 008 receives only oil and grease and suspended solids monitoring.

Condenser cooling water from the on-site power station is discharged without treatment through outfall 009. There is an emergency connection between 009 and 010 which Youngstown reports as normally closed. Flow is normally 64.46 mgd.

Outfall 010 discharges once-through noncontact cooling water from No. 1-4 blast furnaces and heated waste waters from the No. 2 continuous buttweld mill. Also on this line is the emergency overflow from the blast furnace gas cleaning plant. Effluent from the No. 2 continuous buttweld mill is treated in a scale pit to remove oil and solids. Table C-12 for 010 indicates very high suspended solids, 107 mg/ℓ and relatively high oil, 6.4 mg/ℓ. Monthly operating reports include only one parameter, suspended solids, which are based on one 24-hr composite sample/month.

Outfall 001 receives treated effluent from various mills at Youngstown including the No. 1 continuous buttweld mill, billet mill, No. 1 and 2 blooming mills, seamless mill, and the 10-in. and 18-in. merchant mills. All waste lines receive individual treatment from scale pit for oil and solids removal. The flow from six scale pits is then channelled to the Main Scale Pit for further oil recovery. Here noncontact cooling water from the No. 2 open hearth, BOF mill water, primary treated wastes from the seamless mill and boiler house are added to the flow. After treatment at the main scale pit, the effluent then passes to the terminal lagoon for final oil and sludge removal. This treated effluent then is mixed with 6700 gpm untreated mold cooling water from the BOF. An emergency overflow line exists which will by-pass the No. 2 open hearth gas cleaning treatment system directly to the Main Scale Pit. Reported values for oil, phenols and iron indicate inadequate treatment (Table C-12).

In all cases, except for 001, monthly reports are based on one 24-hr composite sample. Source of much flow, treatment, outfall data is Youngstown Sheet & Tube Co. Drawing No. 569849 5/11/72 (U.S. EPA Application file).

10.4 Unreported Discharges

There are four discharges to a lagoon within the breakwater for which no NPDES application for permit is on file. These four discharge 118 mgd into a lagoon which is open to Lake Michigan by a 200-ft opening in the breakwater (U.S. EPA NPDES application file). Youngstown alleges that intake from the lagoon exceeds the 118 mgd and, therefore, that flow is always from the lake, in effect, causing recirculation.

Pickle liquor is stored in a lagoon onsite and removed by an outside contractor for disposal.

11. U.S. STEEL - GARY

11.1 Introduction

U.S. Steel's Gary Works is one of the largest steel mills in the country. There are 829 coke ovens, 12 blast furnaces, 5 sinter plants, and 6 basic oxygen furnaces (3 are under construction). It is a completely integrated mill with all aspects of steel manufacturing represented.

At the Gary works, there are ancillary divisions for specific product manufacturing. These are National Tube Works, American Bridge Division and Universal Atlas Cement Division (NPDES application file).

11.2 General Description - Water Discharges

There are 39 individual outfalls at the Gary Works for which NPDES permits have been requested. These are shown in Figure C-9 and listed in Table C-14. Five of these ourfalls discharge to Lake Michigan and the remaining 34 discharge to the Grand Calumet River, which drains into the Indiana Harbor Canal and therefore to Lake Michigan. Total discharge flow from the Gary Works is 804 mgd. Of this, 552.5 mgd is discharged to the Grand Calumet River through 34 outfalls and 251.5 mgd to Lake Michigan through 5 outfalls. These 34 outfalls from U.S. Steel constitute nearly the entire flow of the Grand Calumet River at 552.5 mgd or 913.4 cfm.

The NPDES application, revised in 1972, indicates 15 Grand Calumet outfalls for which no flow and parameter data is given. Of these 15, two, 005 and 014, have been permanently discontinued. Outfalls 013, 024 and 025 are storm water overflow sewers. A recent U.S. Steel flow drawing GW-202752 (NPDES application) indicates that two outfalls which previously had no flows now are operational. These two are 011 and 038 with flows of 3.5 mgd and 10.4 mgd, respectively.

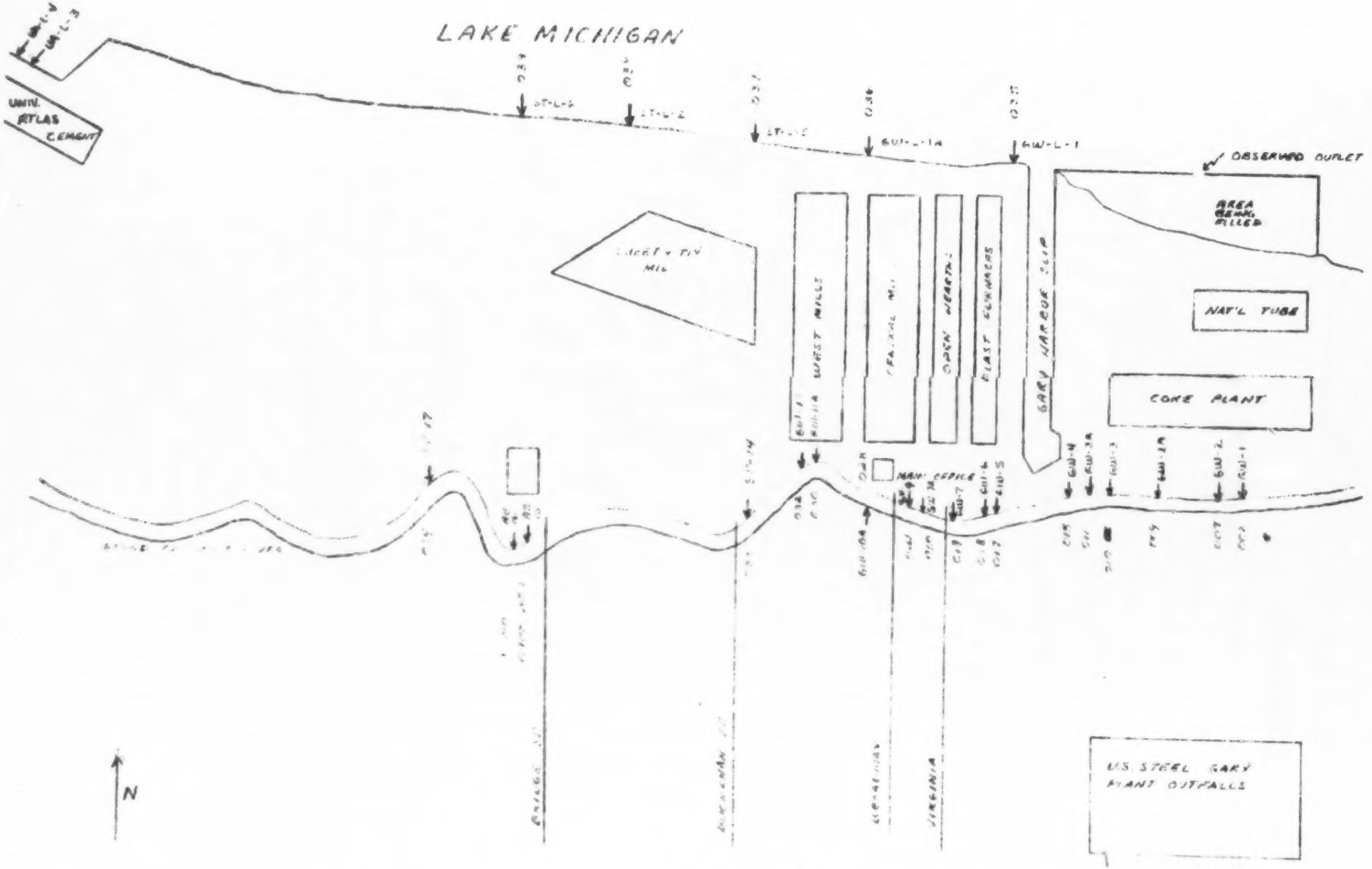

LAKE MICHIGAN
UNIV. ATLAS CEMENT
ST-L-2
GW-L-1
OBSERVED OUTLET
AREA BEING FILLED
NAT'L TUBE
COKE PLANT
WEST MILLS
OPEN HEARTH
BLAST FURNACES
GARY HARBOR SLIP
MAIN OFFICE
GW-7
GW-6
GW-5
GW-4
GW-3A
GW-3
GW-2A
GW-2
GW-1
VIRGINIA
US STEEL GARY PLANT OUTFALLS
N

Figure C-9

DETAIL MAP SHOWING OUTFALLS OF GARY WORKS, U.S. STEEL CORP.
Legend is on following page

Figure C-9

U.S. STEEL - GARY WORKS

OUTFALL LEGEND

NPDES	ISPCB	FLOW MGD	TREATMENT *
002	GW-1	27.3	P W/T
007	GW-2	16.4	P-NT
009	GW-2A	5.7	P W/T
010	GW-3	4.7	P-NT
011	GW-3A	3.5	P W/T
015	GW-4	1.3	P-NT
017	GW-5	64.5	P W/T
018	GW-6	31.8	N-C
019	GW-7	5.7	N-C
020	GW-7A	109.7	N-C
021	GW-9	25.2	P-NT
022	GW-10	NO FLOW	
028	GW-10A	42.3	P W/T
029	GW-11	NO FLOW	
030	GW-11A	71.6	P W/T
031	GW-12	NO FLOW	
032	GW-13	7.7	N-C
033	ST-14	3.1	P-NT
034	ST-17	26.8	P W/T
035	GW-L1	76.8	N-C
036	GW-L1A	28.2	N-C
037	ST-L5	7.0	N-C
038	ST-L2	10.4	N-C
039	ST-L6	71.3	P W/T

* P = process waste
W/T = waste treatment
NT = no treatment
N-C = noncontact cooling water

Table C-14

U.S. STEEL GARY WORKS OUTFALL SUMMARY
Source: NPDES Application

OUTFALL #	FLOW (MGD)	AVERAGE PH	AVERAGE TEMPERATURE WINTER	AVERAGE TEMPERATURE SUMMER
001	-	-	-	-
002	27.3	7.7	61	82
003	.005	7.7	48	68
004	.029	8.0	-	77
005	-	-	-	-
006	.004	7.9	49	70
007	16.4	7.9	61	86
008	-	-	-	-
009	5.7	7.2	57	79
010	4.7	7.6	59	95
011	-	-	-	-
012	-	-	-	-
013	-	-	-	-
014	-	-	-	-
015	1.0	7.9	57	81
016	-	-	-	-
017	64.5	7.5	63	80
018	31.8	7.8	50	75
019	5.7	6.9	59	75
020	[illegible]	7.4	54	93
021	25.1	7.1	-	75
022	-	-	-	-
023	[illegible]	[illegible]	-	97
024	-	-	-	-
025	-	-	-	-
026	-	-	-	-
027	[illegible]	[illegible]	-	95
028	[illegible]	7.9	54	77
029	-	-	-	-
030	[illegible]	7.6	52	75
031	-	-	-	-
032	9.9	7.2	57	68
033	3.1	6.7	61	73
034	26.8	7.5	59	75
035	16.8	7.6	54	75
036	39.2	7.8	53	84
037	7.0	7.7	54	72
038	-	-	-	-
039	71.3	7.3	48	73

There are three categories of active outfalls at the Gary Works, noncontact cooling water, process water without treatment and process water with treatment. The first, noncontact cooling accounts for 264.1 mgd of flow. Outfalls in this category are 018, 019, 032 and 039 which discharge to the Grand Calumet River. Outfalls 35-38 also are noncontact cooling but discharge to Lake Michigan (NPDES application).

Process water which receives no treatment totals 88 mgd, all of which enters the Grand Calumet River. These outfalls include 007, 010, 015, 020, 021, and 033. Wastes from the coke plant, the basic oxygen furnaces, continuous casting line, open hearth furnaces, the No. 3 sinter plant and the atmospheric gas plant are discharged from these lines.

The remaining outfalls 002, 009, 011, 017, 028, 030, 034, and 039 discharge 298.6 mgd of treated waste waters. Wastes from the Gary Tube Works amounting to 27.3 mgd are discharged through outfall 002. Blast furnace waste water amounting to 70.2 mgd are treated and discharged through outfalls 009, 011 and 017.

Wastes from the bar, slab, blooming and 160/210 plate mills are treated and discharged through outfalls 028 and 030. These discharges average 103 mgd.

Wastes from operations conducted at the 80-in. and 84-in. hot strip mills are treated at the terminal treatment plant and discharged through outfall 034 with a flow of 26.8 mgd. Separate waste and treatment lines exist for specific operations of the 80-in. and 84-in. hot strip mills. Wastes averaging 71.3 mgd receive treatment and are discharged from outfall 039.

11.3 Parameter Evaluation

Table C-15 gives the effluent parameter data for all 39 outfalls. These data were originally submitted July 1, 1971. Since then, U.S. Steel has updated their information twice. The values in Table C-15 should therefore indicate present

U. S. Steel
IN 272 - 0808
Gary

Table C-15

U.S. STEEL EFFLUENT CONCENTRATIONS

Application Date: July 1, 1971
Concentrations, mg/ℓ except * = µg/ℓ

OUTFALLS	ALKALINITY	BOD	COD	TOTAL SOLIDS	TOTAL DISSOLVED SOLIDS	TOTAL SUSPENDED SOLIDS	TOTAL VOLATILE SOLIDS	AMMONIA	KJELDAHL NITROGEN	NITRATE	PHOSPHORUS TOTAL	COLOR	TURBIDITY	TOTAL ORGANIC CARBON	TOTAL HARDNESS	SULFATE	SULFIDE	CHLORIDE	CYANIDE	FLUORIDE	ANTIMONY*	IRON*	POTASSIUM	SODIUM	TIN*	ZINC*	GREASE AND OIL	PHENOLS*
001*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
002	105	6.7	29	233	221	12	111	0.2	.9	.16	-	4	3	20.5	140	38	.3	10	-	.3	-	1900	2.5	1.8	20	770	3	-
003	94	1.1	12	159	111	2	46	.7	.9	-	07	3	1	1.7	122	31	.2	12	-	.3	-	300	8	2	-	160	2	-
004	96	11.4	200	790	61	218	197	1.2	2.0	.5	.1	54	5	12	131	47	.2	15	-	-	-	800	6	1.8	-	80	11	-
005*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
006	103	.9	53	218	184	34	71	.2	.4	.2	.03	5	1	3	123	24	.3	13	.02	-	-	800	4.0	1.6	-	50	5	-
007	101	5.8	22	181	172	9	87	.7	2.6	.38	.01	5	2	14.5	76	31	-	12	-	.3	-	1300	9	1.9	-	590	1	32
008*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
009	345	4.9	18	326	291	35	44	5.6	6.6	0.4	.06	9	20	-	174	40	.4	26	.15	1.5	200	2800	18.4	7.9	-	250	3	20
010	111	40	4	239	202	37	127	2.0	2.7	.38	01	80	6	36	158	36	.3	14	-	.1	-	3300	2.8	7.5	20	100	-	180
011*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
012*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
013*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
014*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
015	108	12.6	29	182	174	8	73	0.1	0.4	0.18	-	60	4	8.3	137	25	0.3	10	-	.1	-	1100	2.3	3.5	-	190	3	-
016*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
017	154	8.9	33	257	231	26	107	.1	7.8	.47	.03	55	10	6.5	163	38	0.4	21	4.37	1.0	-	8800	14.8	5.7	-	480	-	288
018	213	7.0	36	184	178	6	30	-	.3	1.0	.05	5	-	4.0	138	27	-	17	.01	.3	-	200	4.8	3.2	-	80	3	4
019	226	6.8	4	182	175	7	7	-	.3	.3	.02	5	1	2.3	138	29	-	13	-	.3	-	200	3.5	8.8	-	50	4	2
020	187	10	36	190	179	11	34	.4	.8	.2	.03	5	2	2.0	137	24	.2	13	-	.3	-	1300	2.2	3.8	-	80	4	10
021	215	2.5	50	224	214	10	49	.7	.7	.1	.03	5	4	2.2	-	26	.2	14	.09	.4	-	1500	-	-	-	90	3	11
022*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
023	125	.2	8	,182	181	1	31	2	.5	-	.01	4	-	2.9	145	22	.2	13	-	.1	-	-	1.9	2.6	-	-	-	-
024*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
025*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
026*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
027	120	1.1	4	175	174	1	36	-	-	-	.01	4	-	2.9	141	23	.3	13	-	.1	-	100	1.9	2.8	-	20	-	-
028	151	.3	8	223	204	19	30	-	1.6	.03	1.6	11	9	1.5	151	30	.3	14	-	.6	-	5800	4.5	2.8	-	2030	2	-
029*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
030	109	1.2	189	189	178	11	29	-	.1	-	.03	10	4	1.1	154	34	.3	12	-	.7		2700	3.1	2.2	-	110	3	-
031*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
032	104	0.4	12	200	195	5	60	-	.2	-	.02	5	4	1.0	596	27	.3	13	-	.3	-	400	1.9	3.4	-	50	3	-
033	103	1.3	20	384	368	16	67	-	.2	-	.16	25	53	3.0	592	135	.3	23	.02	.3	-	2600	3.5	9.1	-	20	4	-
034	78	6.2	43	474	458	16	165	.2	.4	.2	.03	16	9	7.5	572	139	.4	46	-	.8	-	900	9.0	18.2	-	30	5	30
035	115	0.7	19	156	153	3	32	.3	.6	-	.02	3	-	-	-	-	-	12	-	.2	-	-	2.1	3.0	-	20	2	-
036	115	2.8	11	168	158	10	28	-	0.3	-	.02	3	-	-	596	23	.4	11	-	.2	-	100	1.9	3.4	-	20	2	2
037	110	0.7	19	165	159	6	33	.2	.7	-	.02	4	1	-	580	21	.2	11	-	-	-	1100	3.7	2.7	-	150	3	-
038*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
039	97	.7	23	226	205	21	59	.3	.4	.1	.01	4	2	2.0	140	54	.3	12	-	-	-	1800	2	2.5	-	50	3	-

conditions at each outfall, as reported by U.S. Steel. Effluent loads from Combinatorics (1974) are given in Chapters 13 through 18.

Inconsistencies are apparent when the NPDES application data are compared with data from other sources. U.S. EPA and Indiana Stream Pollution Control Board 24-hr analyses were used in the comparison and selected data are given in Table C-16. Most importantly, two outfalls 011 and 038, listed by U.S. Steel as inactive, are now operational. This is confirmed by both EPA and ISPCB analyses and U.S. Steel drawing No. GW-202752 previously referred to above. No data have been submitted to EPA for these outfalls.

Effluent parameter data comparisons given in Table C-17 indicate some other inconsistencies with reported values. Outfall 002 has substantially higher NH_3-N values in recent surveys than in the NPDES application. Outfall 007 has one sample with parameter concentrations several times greater than reported for NPDES. Outfall 009 is substantially higher for phenols and oil while outfall 010 shows a general reduction for most values. Outfalls 015 and 018 are consistent but NH_3-N for 017 is much higher along with phenols and oil. Consistent values occur for 019, 020, 021, 028, 030, 032, 035, 036, 037, and 039. U.S. EPA and ISPCB 24-hr analyses show increases in some parameters for 033 and 034.

11.4 Waste Treatment Facilities

Wastes from the Gary Tube Works are given primary treatment in a scale pit and then combined with untreated coke plant wastes for direct discharge through outfall 002 into the Grand Calumet River. Average flow per day is 27.3 mgd.

Blast furnace gas wash waste water is collected in scalper clarifiers. Overflow from the scalper pits is diverted directly to outfalls 009 and 011. Undiverted wastes continue from the scalpers to two settling basins. After treatment, wastes are channeled to five flue dust pits and from there to outfall 017. Flow from these lines averages 94.4 mgd.

Table C-16

U.S. STEEL GARY WORKS EFFLUENTS
COMPARISON OF EPA ANALYSIS WITH PERMIT APPLICATION, mg/ℓ
Source: NFIC Analysis 6/22/71 from EPA application
NPDES Application July 1971

PARAMETER	OUTFALL 002		OUTFALL 007		OUTFALL 009		OUTFALL 010		OUTFALL 011		OUTFALL 015	
	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.
AMMONIA	0.72	0.2	2.1	0.7	6.7	5.6	0.93	2	6.6	No Flow	0.07	0.1
PHENOL	0.046	N.D.	0.085	0.032	0.483	0.02	0.069	0.18	0.539	"	0.0	-
CYANIDE	0.02	N.D.	0.06	N.D.	1.37	0.15	0.0	N.D.	2.2	"	-	N.D.
SUSP. SOLIDS	26	12	53	9	15.05	35	14	37	36	"	27	8

	OUTFALL 017		OUTFALL 018		OUTFALL 019		OUTFALL 020		OUTFALL 021		OUTFALL 028	
	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat
AMMONIA	6.3	0.1	0.39	N.D.	0.22	N.D.	0.47	0.4	0.13	0.7	0.28	N.D.
PHENOL	0.693	0.288	0.008	0.004	0.0	0.002	0.053	0.018	-	0.011	0.022	N.D.
CYANIDE	4.27	4.37	0.07	0.01	0.01	N.D.	0.18	N.D.	"	0.09	0.04	N.D.
SUSP. SOLIDS	35	26	23	6	34	7	25	11	53	10	16	19

	OUTFALL 030		OUTFALL 031		OUTFALL 033		OUTFALL 034		OUTFALL 035		OUTFALL 036	
	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.
AMMONIA	0.15	N.D.	0.12	N.D.	0.33	N.D.	0.27	0.2	0.09	0.3	0.08	N.D.
PHENOL	0.009	N.D.	0.15	N.D.	0.0	N.D.	0.129	0.03	-	N.D.	-	0.002
CYANIDE	0.0	N.D.	0.02	N.D.	0.02	0.02	0.84	N.D.	0.01	N.D.	0.0	N.D.
SUSP. SOLIDS	29	11	29	5	34	16	38	16	31	3	25	10

	OUTFALL 037		OUTFALL 038		OUTFALL 039	
	EPA	Applicat.	EPA	Applicat.	EPA	Applicat.
AMMONIA	0.1	0.2	0.11	No Flow	0.13	0.3
PHENOL	-	N.D.	0.0	"	0.009	N.D.
CYANIDE	0.0	N.D.	0.0	"	0.0	N.D.
SUSP. SOLIDS	21	6	25	"	25	21

Table C-17

U.S. STEEL GARY WORKS EFFLUENT CONCENTRATIONS, mg/l
COMPARISON OF NPDES, MONTHLY OPERATING REPORTS AND EFFLUENT SURVEYS

Study by: Study Date:	NPDES 7/1/71	EPA Survey 6/22/71	ISPCB Analysis 2/3/73	ISPCB Analysis 6/9/73	U.S. Steel June 1973
Outfall 002					
SS	12	26	10	9.0	21
Fe	1.9	2.92	1.1	0.8	-
NH_3-N	0.2	0.72	0.5	2.0	-
Phenol	-	0.046	0.029	0.015	-
Oil	3.0	NT	5.6	-	3.0
Outfall 007					
SS	9.0	53	76	5.0	31
Fe	1.3	NT	4.1	0.9	-
NH_3-N	0.7	2.1	2.4	2.0	-
Phenol	0.032	0.085	0.029	0.122	
Oil	1.0	-	6.0	-	2.0
Outfall 009					
SS	35	15	77	15	44
Fe	2.8	6.1	0.41	2.3	4.5
NH_3-N	5.6	6.7	4.9	4.7	-
Phenol	0.02	0.483	0.47	0.077	-
Oil	3.0	NT	7.8	-	2.0
Outfall 010					
SS	37	14	3.0	6.0	8.0
Fe	3.3	1.32	1.1	0.5	0.5
NH_3-N	2.0	0.93	0.9	1.2	-
Phenol	0.18	0.069	0.071	0.064	-
Oil	-	NT	6.0	7.8	2.0
Outfall 011					
SS	-	36	16	-	20
Fe	-	9.9	5.5	-	2.0
NH_3-N	-	6.6	4.6	-	-
Phenol	-	0.539	0.182	-	-
Oil	-	NT	2.1	-	1.0
Outfall 015					
SS	8.0	-	8.0	10	11
Fe	1.1	-	0.3	0.7	0.1
NH_3-N	0.1	-	0.1	0.1	-
Phenol	-	-	0.001	0.001	-
Oil	3.0	-	7.0	-	2.0
Outfall 017					
SS	26	35	44	11	29
Fe	8.8	10.3	14	4.0	2.3
NH_3-N	0.1	6.3	4.9	4.8	-
Phenol	0.288	0.693	0.38	0.19	-
Oil	-	-	7.0	-	2.0

Table C-17 (cont.)

Outfall 018 Study by: Study Date:	NPDES 7/1/71	EPA Survey 6/22/71	ISPCB Analysis 2/3/73	ISPCB Analysis 6/8/73	U.S. Steel June 1973
SS	6.0	23	10	3.0	17
Fe	0.2	1.51	0.3	1.1	0.3
NH_3-N	-	0.39	-	0.1	-
Phenol	0.004	0.008	0.008	0.001	-
Oil	3.0	-	4.5	-	1.0
Outfall 019					
SS	7.0	34	8.0	6.0	15
Fe	0.20	1.32	0.4	0.4	0.1
NH_3-N	-	0.22	0.2	-	-
Phenol	0.002	NF	0.019	0.001	-
Oil	4.0	NT	5.7	-	1.0
Outfall 020					
SS	11	25	5	-	75
Fe	1.3	1.98	0.2	-	2.9
NH_3-N	0.4	0.47	0.2	-	-
Phenol	0.018	0.053	0.001	-	-
Oil	4.0	NT	0.1	-	-
Outfall 021					
SS	10	53	8.0	7.0	9.0
Fe	1.5	3.8	0.4	0.2	0.2
NH_3-N	0.7	0.13	0.1	0.1	-
Phenol	0.011	NT	0.01	0.04	-
Oil	3.0	-	-	-	1.0
Outfall 028					
SS	19	16	24	-	24
Fe	5.8	6.3	8.0	-	1.2
NH_3-N	-	0.28	0.2	-	-
Phenol	-	0.022	0.010	-	-
Oil	2.0	-	8.7	-	3.0
Outfall 030					
SS	11	29	13	-	14
Fe	2.7	6.8	5.1	-	0.9
NH_3-N	-	0.15	0.2	-	-
Phenol	-	9.0	0.003	-	-
Oil	3.0	-	7.4	-	<2.0
Outfall 032					
SS	5.0	29	25	7.0	3.0
Fe	0.4	4.2	11.0	0.5	0.5
NH_3-N	-	0.12	0.2	0.1	-
Phenol	-	0.015	0.001	0.012	-
Oil	3.0	-	7.3	4.1	1.0
Outfall 033					
SS	16	34	55	30	23
Fe	2.6	16.4	25	14	7.7
NH_3-N	-	0.33	0.4	0.3	-
Phenol	-	NF	0.0001	0.0001	-
Oil	4.0	-	5.7	4.4	1.0

Table C-17 (cont.)

Outfall 034 Study by: Study Date:	NPDES 7/1/71	EPA Survey 6/22/71	ISPCB Analysis 2/2/73	ISPCB Analysis 6/19/73	U.S. Steel June 1973
SS	16	38	18	-	27
Fe	0.9	4.10	4.10	-	5.0
NH_3-N	0.2	0.27	0.2	-	-
Phenol	0.030	0.129	0.146	-	-
Oil	5.0	-	7.9	-	7.0
Outfall 035					
SS	3.0	31	4.0	-	5.0
Fe	-	NT	0.2	-	0.1
NH_3-N	0.3	0.09	0.1	-	-
Phenol	-	NT	0.001	-	-
Oil	2.0	-	5.1	-	1.0
Outfall 036					
SS	10	25	4.0	-	8.0
Fe	0.1	0.95	0.3	-	0.1
NH_3-N	-	0.08	-	-	-
Phenol	0.002	NT	0.001	-	-
Oil	2.0	-	3.7	-	1.0
Outfall 037					
SS	6.0	21	8.0	6.0	12
Fe	1.1	4.5	2.9	1.2	1.8
NH_3-N	0.2	0.1	-	0.1	-
Phenol	-	NT	0.001	0.001	-
Oil	3.0	-	5.5	-	1.0
Outfall 038					
SS	-	25	-	6.0	13
Fe	-	107	-	0.4	0.3
NH_3-N	-	0.11	-	0.1	-
Phenol	-	NF	-	0.001	-
Oil	-	-	-	-	2.0
Outfall 039					
SS	21	25	14	3	6
Fe	1.3	5.4	1.9	0.5	0.3
NH_3-N	0.3	0.13	0.2	0.1	-
Phenol	-	0.009	0.016	0.001	-
Oil	2	-	4.5	-	2

Wastes from bar, slab, blooming and the 160-210 plate mills are diverted to three lagoons where oil is skimmed and collected. Wastes then pass through a scale pit for additional oil and sludge removal. The treated effluent is discharged through outfalls 028 and 030 with a combined average flow of 141.8 mgd.

The terminal treatment plant receives wastes from the 80-in. and 84-in. hot strip mills. Treatment includes four primary separators, two settling tanks, flocculation clarifiers and a centrifugal oil separator. Discharge is through outfall 034 at 26.8 mgd.

The last major treatment system is the 84-in. hot strip mill filtration plant which receives wastes from both the 80-in. and 83-in. HSM's. There are through-primary scale pits, through-secondary scale pits, one finishing pit, 12 sand filters, a thickener and vacuum filters. Flow of 71.3 mgd from this facility is discharged to Lake Michigan through outfall 039.

11.5 Alternate Waste Lines

Wastewater recirculation at the Gary Works accounts for 22.4 mgd. The 80-in. H.S.M., the 18-in. bar mill, the 160/210 plate mill and basic oxygen shops utilize recirculation for some process lines. Future construction at the 84-in. H.S.M. will add an additional 14.4 mgd to recycle systems.

A deep well disposal system is operational at Gary and receives pickle liquor from the Gary Tube Works and the U.S. Steel - Waukegan facility. The depth of the well is 4303 ft and wastes are injected at 210 gpm at 200 psi. Waste pickle liquor consists of sulfuric acid 8-37%, ferric sulfate 18-25%, ferric chloride 15-20% and chromic acid 2-6%.

Coke plant wastes from the ammonia concentration operation are diverted to the Gary Municipal Sewage Treatment Plant.

11.6 American Bridge and Universal Atlas Cement Divisions

These ancillary divisions of U.S. Steel do not have NPDES applications on file for any discharges even though other sources, as follow, do indicate the possibility of such discharges. A map of discharges (Figure C-9) from U.S. Steel prepared by personnel from the Indiana Stream Pollution Control Board on 8/23/73 (in ISPCB files) indicates four unreported discharges; two from the American Bridge Division and two from Universal Atlas Cement. The American Bridge outfalls designated AB-15 and AB-16 are located on the Grand Calumet River at Bridge St. Those outfalls from Universat Atlas Cement are designated UA-L-3 and UA-L-4 on Figure C-10. They are located on Lake Michigan. Furthermore, the existence of UA-L-4 is confirmed by U.S. Steel since they include this outfall in monthly operating reports to the ISPCB. Only data for oil, suspended solids and iron are given. Flow is not reported.

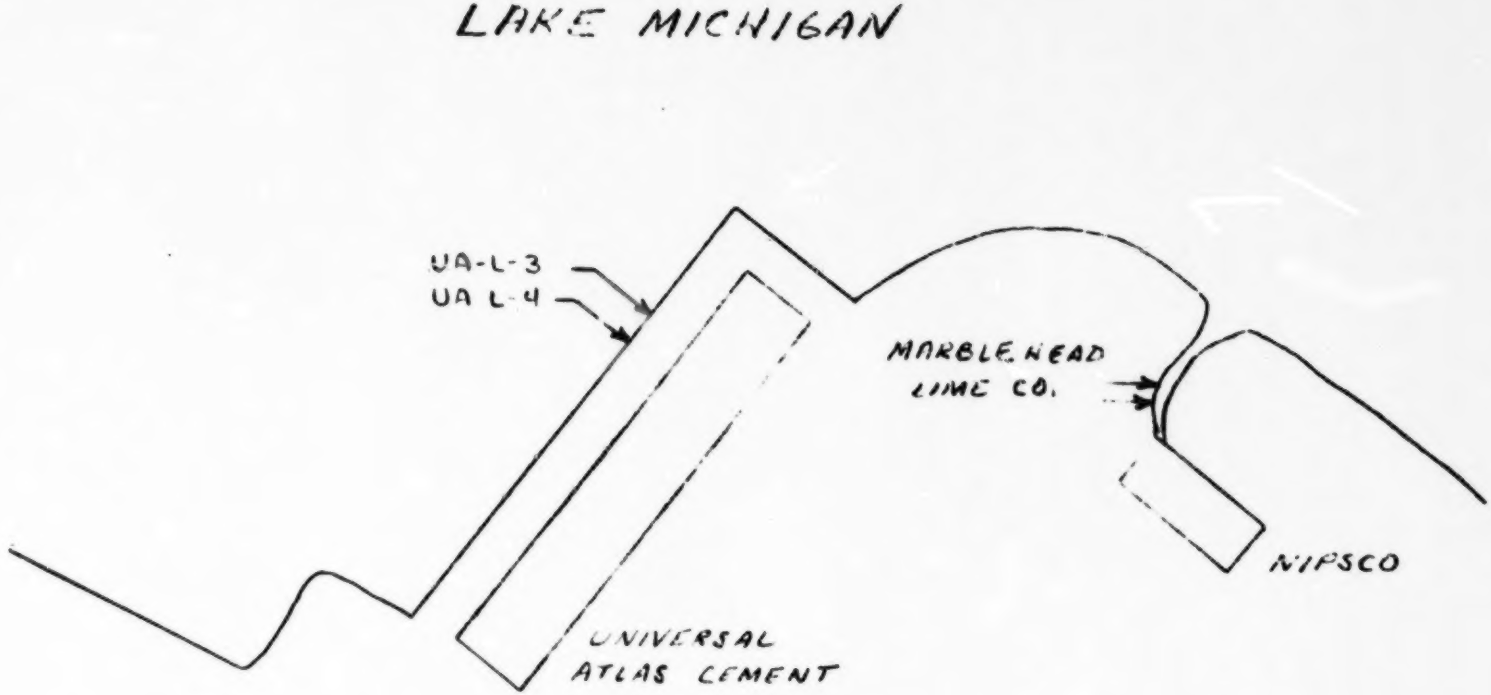

LAKE MICHIGAN
UA-L-3
UA L-4
MARBLE HEAD
LIME CO.
UNIVERSAL
ATLAS CEMENT
NIPSCO

Figure C-10

DETAIL MAP OF BUFFINGTON HARBOR DISCHARGERS

12. U.S. STEEL SOUTH WORKS

12.1 Introduction

The U.S. Steel South Works is an integrated steel mill producing 22,592 tons of steel per day (Attorney General Report, page 4). Coke, however, is produced at the U.S. Steel facility in Gary, Indiana and shipped to the South Works. Production facilities which produce waste water discharges are the blast furnaces, electric furnaces, basic oxygen process, sintering plant, casting plants and bar mills.

The facility is located at the junction of the Calumet River with Lake Michigan. There are two slips, the north and south slips, which contain two outfalls shown in Figure C-11. The North Slip is separated from Lake Michigan by an air curtain to retain any oil spills. At the origin of the North Slip is the main plant water intake. Net flow through the North Slip is reported by U.S. Steel as toward the intake, never to the lake (Personal communication with plant officials).

12.2 Outfall Descriptions

The company has reported six outfalls in their NPDES application. Outfalls 001, 002 and 003 discharge to Lake Michigan. Outfalls 004 and 005 discharge to the Calumet River and outfall 006 discharges to the South Slip (see Figure C-11). As reported June 18, 1971, in the NPDES application, there is only one process water discharge, i.e., outfall 006. Noncontact cooling water is discharged through outfalls 001, 002, 003 and 005. Outfall 004 is reported as inactive except for storm runoff.

12.3 Evaluation

NPDES application data from 1971 can not be considered valid to the present discharge. On January 18, 1971, U.S. Steel, the Illinois Attorney General and the Metropolitan Sanitary District of Greater Chicago (MSD) entered into a stipulated

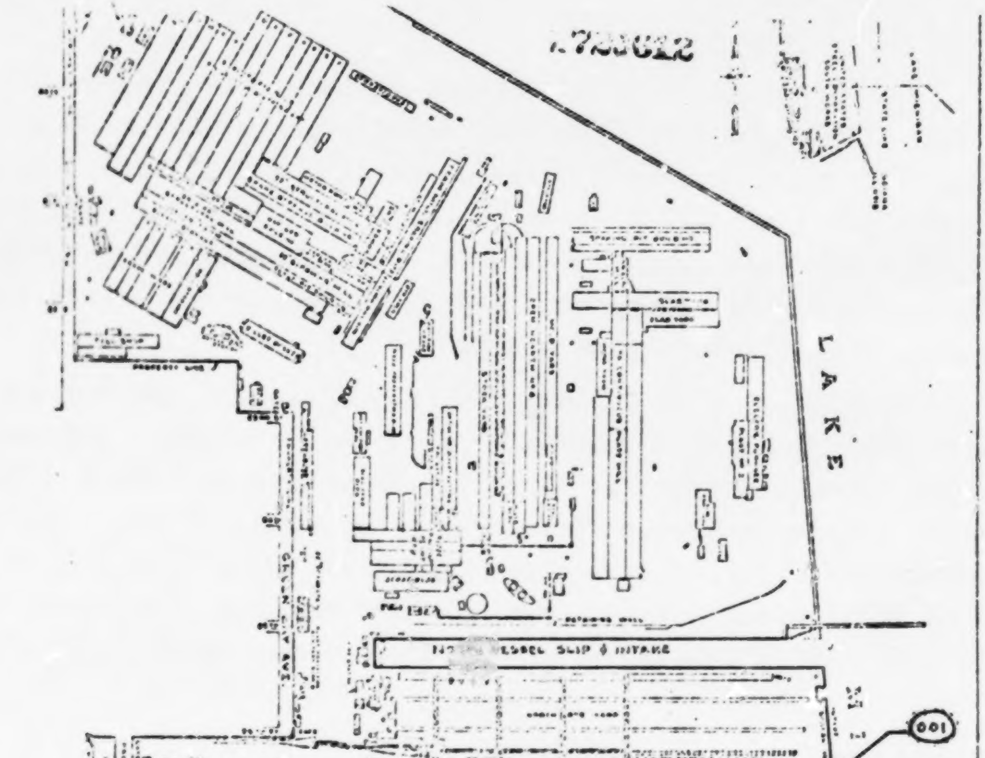

LAKE MICHIGAN
NORTH VESSEL SLIP & INTAKE
001
002
003
004
005
006
333.4 R
332.9 R
CALUMET RIVER
DISCHARGE
IN LAKE MICHIGAN & CALUMET RIVER
AT CHICAGO
COUNTY OF COOK, STATE OF ILLINOIS
APPLICATION BY UNITED STATES STEEL CORPORATION
SHEET 1 OF 1

Figure C-11
OUTFALL LOCATIONS

Reproduced from best available copy.

agreement leading to the complete recycle of process waste water with a blowdown entering the sewers of the MSD. The Order (#69CH3334 and 67CH5772) was the culmination of a legal battle lasting three years.

Specifically, the Order provides that:

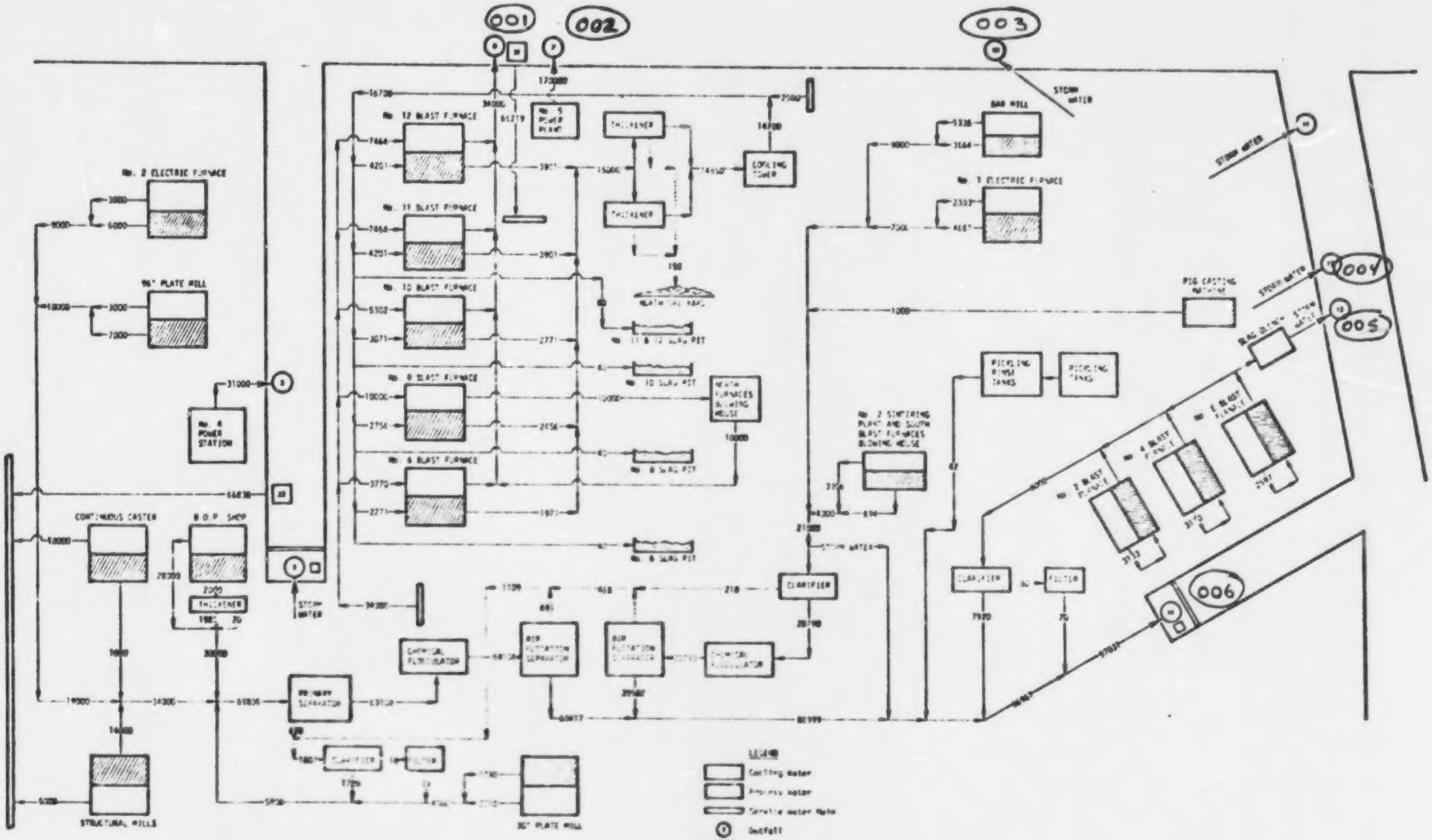
- A recycle system for process water from the "South blast furnaces shall be completed by October 31, 1972.
- A recycle system for process water from mill operations shall be constructed according to the following schedule.
  - Recycle for the "South" side mills shall be completed not later than October 31, 1974
  - The blow-down from the mill recycle system shall be no greater than 3700 gpm and discharged to the MSD.

U.S. Steel South Works is presently in the process of complying with this stipulated agreement. The treatment system is shown in Figure C-12.

A report prepared for the Illinois Attorney General (Data Graphics, Inc. 1970) proposed effluent concentrations which correspond to interim levels achieved by the on-going construction of recycle systems, as given in Table C-18. These effluent reductions will result in the following loads, based on flow at 17.4 mgd:

INTERIM EFFLUENT CONCENTRATIONS AT OUTFALL 006*

Parameter	Load, lb/day	Concentration, mg/ℓ
Suspended solids	15,025	10.3
Oil	1,586	10.9



001
002
003
004
005
006
STORM WATER
No. 2 ELECTRIC FURNACE
96" PLATE MILL
No. 4 POWER STATION
CONTINUOUS CASTER
B.O.P. SHOP
THICKENER
STRUCTURAL MILLS
No. 12 BLAST FURNACE
No. 11 BLAST FURNACE
No. 10 BLAST FURNACE
No. 8 BLAST FURNACE
No. 6 BLAST FURNACE
No. 5 POWER PLANT
THICKENER
COOLING TOWER
No. 11 & 12 SLAG PIT
No. 10 SLAG PIT
No. 8 SLAG PIT
No. 6 SLAG PIT
NORTH FURNACES BLOWING HOUSE
PRIMARY SEPARATOR
CHEMICAL FLOCCULATOR
AIR FLOTATION SEPARATOR
CLARIFIER
FILTER
30" PLATE MILL
BAR MILL
No. 3 ELECTRIC FURNACE
PIG CASTING MACHINE
PICKLING RINSE TANKS
PICKLING TANKS
No. 2 SINTERING PLANT AND SOUTH BLAST FURNACES BLOWING HOUSE
SLAG QUENCH
No. 2 BLAST FURNACE
No. 4 BLAST FURNACE
No. E BLAST FURNACE
LEGEND
Cooling water
Process water
Service water Note
Outfall
Water Intake
9000
3000
6000
10000
7000
31000
66830
28300
2200
3000
19300
34300
14000
5300
16720
34000
65219
173000
7464
4201
5302
3071
10000
2756
3770
2271
3907
2771
2656
1071
15000
14550
14700
2500
150
80199
60017
29700
21300
4300
1000
7920
70
57037
9800
5336
3164
7500
2333
4667
3153
3170
2507

Figure C-12

EXISTING PROPOSED WATER USE AND WASTEWATER SYSTEM
(all flows are in gallons per minute)

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Table C-18

U.S. STEEL SOUTH WORKS
INTERIM EFFLUENT CONCENTRATIONS AT OUTFALL 006

Parameter	Load, lb/day	Proposed effluent concentration,* mg/ℓ	
		Average	Maximum**
Suspended solids	48,080	41.3	80.4
Oil	3,172	2.73	5.3
Phenol	114	0.097	5.19
Cyanides	145	0.124	0.24
Fluorides	238	0.204	0.39
Ammonia	114	0.097	0.19
Acid equivalents	5,083	4.37	8.50

*Data from Datagraphics Report, July, 1970, Wastewater Treatment, Reuse, and Disposal at South Works, U.S. Steel Corp., Chicago, Ill.

**Based on 71.7 mgd flow.

It is unclear at what stage U.S. Steel is presently at in its construction schedule; however, total recycle should take place by October 31, 1974.

Discharges of cooling water with flows are indicated in Figure C-12.

REFERENCES

Combinatorics, Inc., 1974

Load allocation study of the Grand Calumet River and Indiana Harbor Ship Canal, Report to State of Indiana, Stream Pollution Control Board.

Council on Economic Priorities, 1973

Environmental Steel, Washington, D.C.

Datamatics, 1970

Wastewater treatment, reuse, and disposal, Report at South Works, U.S. Steel Corp., Chicago, Ill, July 1970.

People of the State of Illinois and the Metropolitan Sanitary District of Greater Chicago vs Inland Steel Co., 1974

Circuit court of Cook County, Illinois.

APPENDIX D

MUNICIPAL SOURCES AND COMBINED SEWER OVERFLOWS

MUNICIPAL SOURCES AND COMBINED SEWER OVERFLOWS

This Appendix describes the status (on January 1, 1974) of the sewage treatment plants and the combined sewer outfalls and presents available data on the flows and loads of pollutants. In general it will be seen that the indicators of municipal wastes in this area have not improved recently, and may even have deteriorated in spite of improvements in some facilities. This is caused partly by delays in construction and partly by diversion of steel mill and other industrial wastes to certain facilities. A list of plants is given in Table D-1, and maps in Figures D-1 and 4.1 (Chapter 4, Vol. I of this report).

1. EAST CHICAGO SANITARY DISTRICT FACILITIES

The East Chicago Sanitary District (ECSD) was formed in 1929 and includes the corporate boundary of the city of East Chicago. The total population served is about 52,000, for which the sewage treatment plant is adequate; however, about 12 major industries also discharge to the ECSD sewers, and this creates problems discussed below. The district has a predominantly combined sewer system. This description is from information provided to Mr. Sweeney (1973) by personnel of the ECSD.

1.1 The District Wastewater Treatment Plant

The District wastewater treatment plant (WTP) is located on the west branch of the Grand Calumet River in East Chicago (see "B" on map, Figure 4.1, Chapter 4, Vol. I of this report). The plant was put into operation in 1942 and has a 20-mgd activated sludge type secondary treatment capacity.

Average discharge flow is about 12-13 mgd, but flows approaching the 20-mgd plant design capacity are common. Some flow data and effluent loads are given in Table D-2.

A 140-150 million gallon detention basin has been constructed on the plant property, and its surface aerators provide additional oxidation capability.

Table D1

SUMMARY OF MUNICIPAL WTP DISCHARGES IN CALUMET AREA

Map Ref. No.	System	Type of sewer[1]	Secondary treatment capacity, mgd	Average flow, mgd	Receiving waterway	Inflow Point to Lake Michigan	Comment
	Public Systems						
1.	Hammond S. D.		36.0	36.0	Grand Calumet R.	I.H.C.*	Under construction for expansion to 48.0 MGD capacity. Contract area. Contract area Contract Area
	Hammond	C,S					
	Munster	C,S					
	Whiting	C					
	Griffith	C,S					
	Highland	C,S					
2.	East Chicago S.D.						
	East Chicago		20.0	12.5	Grand Calumet R.	I.H.C.	Much Industrial wastewater.
3.	Gary S.D.						
	Gary	C,S	60.0	46.0	Grand Calumet R.	I.H.C.	
	E. Gary	C,S					
	Merrillville	C,S					
4.	Portage	S	3.0	1.2	Burns Ditch	Burns Ditch	
5.	Chesterton		1.5	1.2	Little Calumet R.	Burns Ditch	
	Chesterton	C,S					
	Porter	C,S					
6.	Valparaiso		6.0	3.5	Salt Creek	Burns Ditch	Newly expanded
7.	Hobart	S	2.1	2.5	Deep River	Burns Ditch	Plant overloaded
8.	Crown Point	C,S	1.8	1.7	Beaver Dam Creek to Turkey Creek	Burns Ditch	

*Flow often is west to Illinois.

[1] c is combined; s is separated.

Table D1 (cont.)

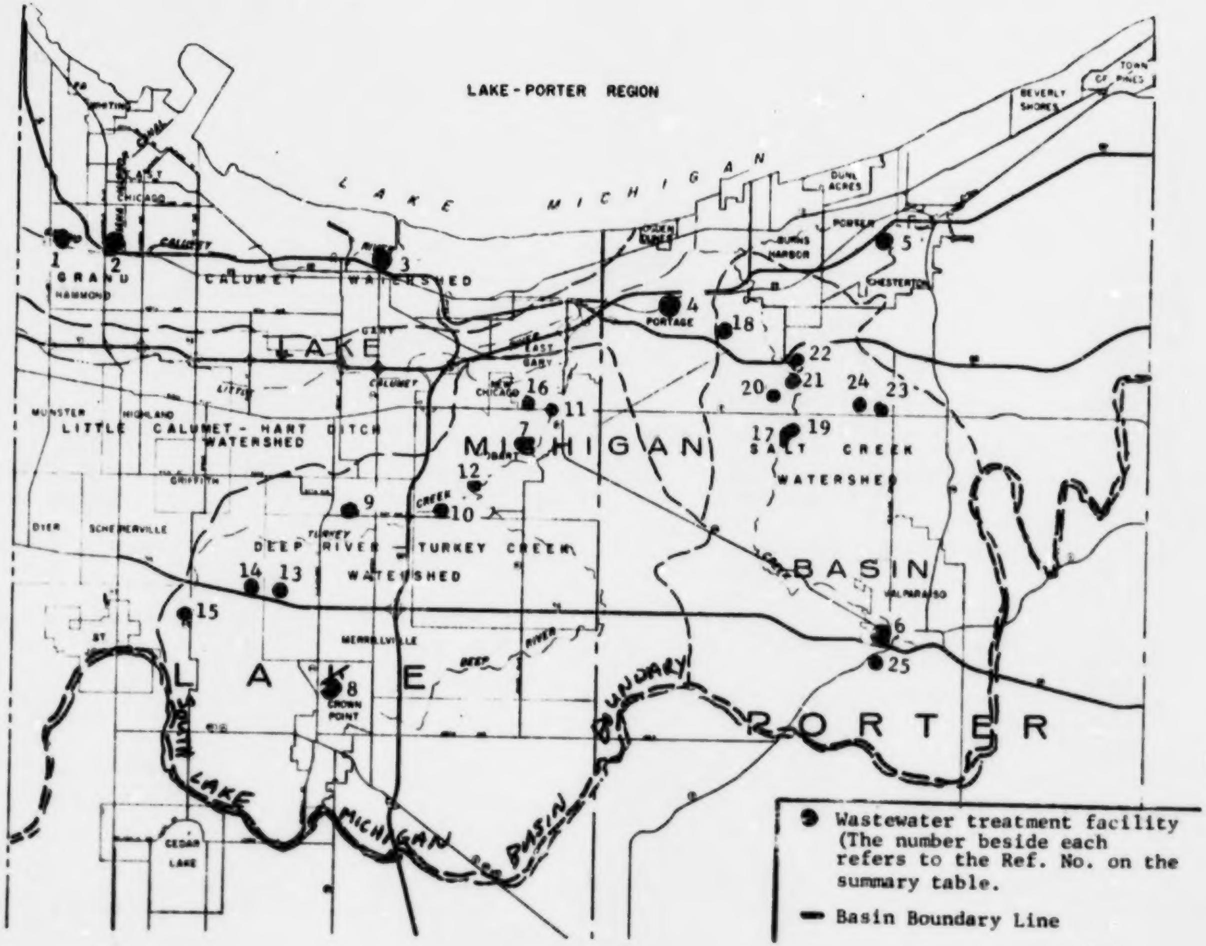
REF. No.	System	Type of Sewer^1	Secondary Trt Cap. (MGD)	Avg. Flow (MGD)	Receiving Waterway	Inflow Pt. to Lake Mich.	Comment
	Semi-Public & Private Systems						
9.	Bon Air Subd.	S	0.36	-	Turkey Creek	Burns Ditch	
10.	Brookview Terrace Subd.	S	0.10	-	Turkey Creek	Burns Ditch	
11.	Knob Hill Subd.	S	0.10	-	Deep River	Burns Ditch	
12.	Lake George Subd.	S	0.10	-	Deep River	Burns Ditch	
13.	Lincolns Gardens	S	0.20	0.16	Turkey Creek	Burns Ditch	
14.	Rolling Hills Est. Subd.	S	0.035	-	Turkey Creek	Burns Ditch	
15.	Schererville Hts.	S	0.06	0.05	Turkey Creek	Burns Ditch	
16.	Triple A. Util.	S	0.05	-	Deep River	Burns Ditch	
17.	Ideal Dev. Inc.	S	0.70	-	Salt Creek	Burns Ditch	
18.	Neighborhood Util.	S	0.10	-	Salt Creek	Burns Ditch	Expansion to 2.0 MGD
19.	South Haven Subd.	S	1.4	0.5**	Salt Creek	Burns Ditch	
20.	Pleasant Valley Mobile Home Park	S	0.08	0.013**	Squirrel Creek	Burns Ditch	

** Estimated.

Table D1 (cont.)

REF. No.	System	Type of Sewer[1]	Secondary Trt Cap. (MGD)	Avg. Flow (MGD)	Receiving Waterway	Inflow Pt. to Lake Mich.	Comment
	Semi-Public & Private Systems						
21.	Robbinswood Subd.	S	0.078	0.026	Salt Creek	Burns Ditch	
22.	Oak Tree Park Mobile Home Park	S	0.063	0.017	Salt Creek	Burns Ditch	
23.	Elmwood Mobile Home Park	S	0.048	0.04	Damon Run to Salt Creek	Burns Ditch	
24.	Sands Mobile Home Park	S	0.015	0.01**	Damon Run to Salt Creek	Burns Ditch	
25.	Porter County Home	S	Septic Tank	0.003	Salt Creek	Burns Ditch	

**Estimated.


LAKE-PORTER REGION
LAKE MICHIGAN
WHITING
EAST CHICAGO
CANAL
CALUMET
HAMMOND
GRAND CALUMET WATERSHED
RIVER
GARY
LAKE
CALUMET
LITTLE
MUNSTER
HIGHLAND
LITTLE CALUMET - HART DITCH WATERSHED
GRIFFITH
DYER
SCHERERVILLE
EAST GARY
EAST CHICAGO
MICHIGAN
HOBART
CREEK
TURKEY
DEEP RIVER - TURKEY CREEK WATERSHED
MERRILLVILLE
DEEP RIVER
CROWN POINT
ST
CEDAR LAKE
SOUTH LAKE MICHIGAN BASIN BOUNDARY
OGDEN DUNES
PORTAGE
BURNS HARBOR
DUNE ACRES
PORTER
CHESTERTON
BEVERLY SHORES
TOWN OF PINES
SALT CREEK WATERSHED
BASIN
VALPARAISO
PORTER
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● Wastewater treatment facility (The number beside each refers to the Ref. No. on the summary table.
━ Basin Boundary Line

Figure D-1

MAP OF LAKE-PORTER REGION WASTEWATER TREATMENT FACILITIES

Table D-2

YEARLY EFFLUENT AVERAGES OF THE THREE MAJOR SANITARY DISTRICTS

				BOD			Suspended solids		
Municipality	Year	WTP design capacity, mgd	Flow, mgd	Raw, mg/ℓ	Final, mg/ℓ	Load, lb/day	Raw, mg/ℓ	Final, mg/ℓ	Load lb/day
Hammond	1966	36.00	35.1	182	22	6,446	264	23	6,739
	1967		32.1	156	21	5,628	252	27	7,236
	1968		33.0	223	39	10,725	407	37	10,175
	1969		35.	196	24.4	7,203	369	31	9,270
	1970		38	151	22.6	7,190	234	35	11,199
	1971		36	187	20.9	6,431	361	29	8,924
	1972		38	172	36.2	11,532	229	46	14,750
East Chicago	1966	20.00	11.3	91	9	846	103	12	1,128
	1967		11.8	154	16	1,568	110	18	1,764
	1968		11.5	150	28	2,688	111	27	2.592
	1969		11.9	142	32	3,175	124	28	2,778
	1970		11.0	128	43	3,944	127	34	3,119
	1971		12.1	147	48	4,843	113	30	3,027
	1972		16.1	131	54	7,250	147	50	6,713
(through 9/73)	1973		14.4	153	56	6,725	197	39	4,683
Gary	1966	60.00	42.1	142	10	3,510	-	43	15,093
	1967		46.1	89	16	6,144	239	43	16,512
	1968		48.5	101	11	4,444	200	21	8,484
	1969		44.06	123	12	4,409	202	24	8,819
	1970		45.5	119	16	6,071	224	34	12,901
	1971		40.1	123	22	7,357	230	43	14,380
	1972		46.5	135	29	11,246	225	51	19,778

Source: Hammond S.D. WTP Monthly Operating Reports.
East Chicago WTP Monthly Operating Report.
Annual Report Gary Sanitary District.

Interim phosphorus removal facilities were put into operation in June 1972, and permanent facilities were operational by September 1973. The 80% P removal recommendations of the 1968 Lake Michigan Enforcement Conference is being met according to District personnel. Effluent concentration data in Table D-3 indicate that the 1 mg/ℓ P concentration limit recommended as an objective by the 1972 Lake Michigan Enforcement Conference is not always being met. Other parameters are less well controlled, as will be discussed below.

Chlorination of effluent discharged to the Grand Calumet River is provided, but this is not effective in killing bacteria. The reasons for this are discussed in the following.

1.2 Planned Plant Improvements

The Four-State Lake Michigan Enforcement Conference Technical Committee (1968) put a July 1, 1977, deadline on completion of advanced waste water treatment (AWT) by the ECSD, and the District anticipates meeting this deadline. AWT plans were approved by the Indiana Stream Pollution Control Board (ISPCB) and the U.S. EPA, but the District is now reconsidering the methods involved and finds them too costly. Possibly, new AWT plans will be submitted, and it is probable that feasibility planning of WTP expansion to increase the design capacity from its existing 20-mgd to a 26-30 mgd capacity may take place.

The ECSD is planning on a Fiscal 1974 infiltration study which is expected to cost $200,000 and will help determine whether sewer repair, WTP expansion, or both is necessary to handle the problem of the increased flows to the WTP.

Problems of influent loads from industries are recognized by ECSD.

A program of industrial influent analysis will be undertaken in 1974, and it is estimated by the District that an additional $150,000 for laboratory equipment will be spent to monitor influents. Influent regulations so far have been limited to informal agreements with industry.

Table D-3

EAST CHICAGO SANITARY DISTRICT WASTEWATER TREATMENT PLANT REPORT*
1973

		BOD Mg/1		SS Mg/1		NH_3 Mg/1		Cn^- Mg/1		Phenol µg/1		Fe mg/1		PO_4^- Mg/1		NO_3^- Mg/1		% Purif.	
	MGD	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	BOD	SS
JAN.	18.6	84	26	182	38	76	75	.40	.33	5.6	.34	3.7	1.2	1.3	0.2	6.2	3.1	69	79
FEB.	18.5	125	36	225	35	79	88	1.2	.23	1.18	.015	3.1	1.0	1.3	0.2	5.8	2.9	71	85
MAR.	12.0	95	48	-	42	93	98	1.12	.49	1.40	.02	-	1.6	-	0.3	5.8	1.7	66	78
APR.	12.6	130	45	332	78	76	76	1.30	1.16	2.3	.264	3.3	1.4	1.0	0.3	4.6	1.70	65	78
MAY	12.6	155	63	160	33	94	92	1.34	0.18	1.25	.02	3.6	1.3	1.0	0.4	4.6	2.3	59	79
JUN.	11.2	163	66	146	31	100	96	1.04	0.63	2.16	.23	2.9	1.5	1.1	0.3	4.3	1.7	59	78
JUL.	10.9	180	70	201	29	117	121	0.85	0.43	1.39	.06	2.6	0.9	1.3	0.3	3.2	1.9	61	85
AUG.	18.1	195	75	215	38	100	111	0.88	0.53	4.3	1.24	3.4	1.3	1.2	0.2	3.6	1.7	62	87

*Source: East Chicago S.D. WTP Monthly Operating Reports

1.3 Plant Performance and Effluents

Analysis of effluents from the WTP are shown in Table D-3. The most striking deficiency is in NH_3-N levels in the effluent. This plant is an important source of NH_3, and is causing violations of NH_3-N values in the Lake, as described in Chapter 13. The load is 10,000 lb/day NH_3-N with a maximum of 30,000 lb/day (Combinatorics 1974). That the effluent has deteriorated can be seen by comparing Table D-3 with Table D-4.

Excessive NH_3-N has another harmful effect, in that it makes effective chlorination impossible. Chlorine is known (Palin 1973) to react with NH_3, and residual chlorine is needed to sterilize the effluents. Table D-3 does not report the bacterial counts in the plant effluents, but we believe that they are very high. On November 30, 1973, IITRI sampled the Grand Calumet River upstream and downstream of the plant outfall, and found high total coliform concentrations downstream (Table 16.4, Chapter 16, Vol. I of this report). Effluents from EC WTP appear to be the largest source of coliform bacteria measured in the IHC as reported in Chapter 16.

Table D-4*

EAST CHICAGO STP
SPECIAL EFFLUENT ANALYSIS, mg/ℓ

Year	NH_3	Nitrate	Phenol	Iron	Phosphorus	Cyanide
1966	18.9	-	0.009	-	3.6	0.18
1967	23.6	-	0.010	-	2.8	0.19
1968	48.5	0.71	0.232	1.6	3.8	0.28

*(Technical Committee on Water Quality 1970)

The amount of NH_3 is far in excess of what would be expected in a plant serving a population the size of East Chicago. The source of NH_3 is the waste water from steel mills, primarily from Inland Steel and Youngstown Sheet and Tube. This is shown in testimony presented in a lawsuit (People of the State of Illinois vs Inland Steel Co. 1974). The NH_3 comes from ammonia stills used in coke oven operations. In addition to NH_3, there are also problems with other wastes. One of these is excess lime, which is needed to raise the pH so that the NH_3 can be distilled off. Mechanical problems with the lime slaker sometimes result in excesses of lime being sent to the sewer. When it reaches the WTP, this lime can suddenly raise the pH, killing the bacteria that function in the activated sludge process. The result is an upset and a period of very poor sewage treatment. Other wastes can be related to industrial sources as well. These include the relatively high levels of cyanide and phenol shown in Table D-4. Data are not given on oil, but its presence might be expected, as well as heavy metals.

1.4 Pretreatment Guidelines

U.S. EPA guidelines (1973) for municipal treatment plants receiving federal grants state that (p. 13) it is important that no discharge from any source to the publicly owned treatment works interfere with treatment processes or result in a violation of effluent limitations. There must therefore be a legal basis for regulating and controlling all discharges to the publicly owned treatment works, such as a municipal ordinance. It may be necessary to establish a local system which will allocate waste loads to industrial users so that biological treatment processes are not inhibited and to ensure that effluent limitations are met.

The guidelines generally do not set limits on the concentrations of various pollutants discharged to the sewers, except that they specify a 50 mg/ℓ limit for oil from refineries. The guidelines specify several pretreatment processes that may be used by petroleum refiners, steel mills, and starch syrup plants, but these do not appear to consider all of the problems to which the East Chicago plant is exposed due to ammonia discharges.

Pretreatment guidelines for the steel industry are also given in the EPA Iron and Steel Guidelines (1974). These guidelines recommend that sufficient pretreatment be given so that after further treatment by the municipal plant, the effluents will meet the standards for new sources. The various processes that can be used for removal of ammonia and other pollutants are listed. Some municipalities have imposed limits on discharges of certain pollutants to sewers, with rather high charges for industries that exceed these limits. We recommend that such a course be undertaken by East Chicago.

1.5 Storm and Combined Sewer Overflows

The three major Calumet area sanitary districts are also required to treat or control combined sewer overflows. The outfalls from these combined sewer overflows are shown on the map of Figure D-2.

The ECSD is responsible for two combined sewer overflow discharges to the Grand Calumet River (GCR), one to the IHC and one storm water discharge to the IHC. These are shown in Figure D-2 and Table D-5. There is no flow monitoring at this time, but Table D-5 includes peak flow estimates.

The District constructed a 140-150 million gallon detention lagoon in 1971 to hold the diverted flow from several combined sewer overflows for treatment. The completion of the project requires increases in the pumping capacity of the system, which has been delayed due to bond sale problems. The lagoon is thus

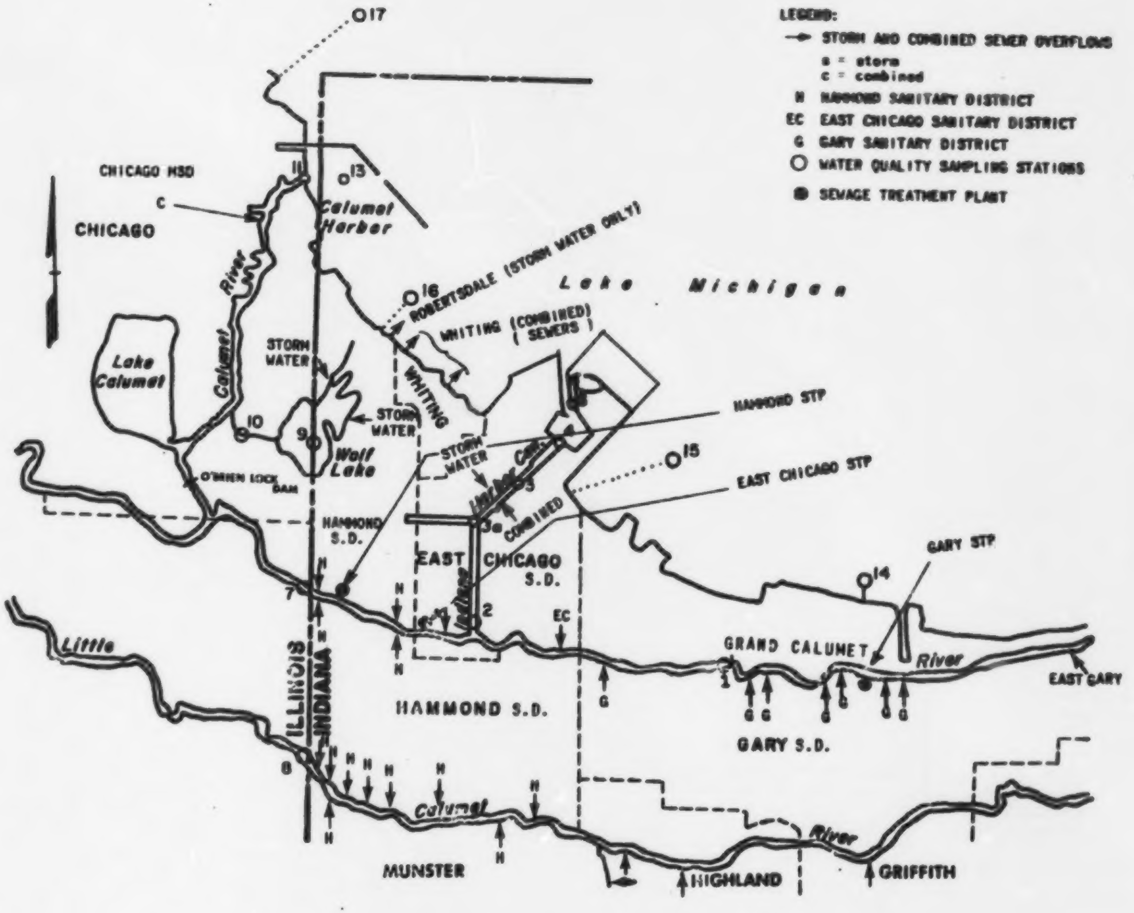
O17
CHICAGO MSD
C
CHICAGO
11
O13
Calumet Harbor
Calumet River
Lake Calumet
STORM WATER
10
9
Wolf Lake
STORM WATER
O'BRIEN LOCK DAM
O16
ROBERTSDALE (STORM WATER ONLY)
WHITING (COMBINED) (SEWERS)
WHITING
Lake Michigan
STORM WATER
Canal
3
3a
COMBINED
HAMMOND STP
O15
EAST CHICAGO STP
HAMMOND S.D.
EAST CHICAGO S.D.
2
7
ILLINOIS
INDIANA
H
EC
G
O14
GARY STP
GRAND CALUMET River
1
EAST GARY
HAMMOND S.D.
GARY S.D.
Little Calumet River
8
MUNSTER
HIGHLAND
GRIFFITH
LEGEND:
STORM AND COMBINED SEWER OVERFLOWS
s = storm
c = combined
H HAMMOND SANITARY DISTRICT
EC EAST CHICAGO SANITARY DISTRICT
G GARY SANITARY DISTRICT
○ WATER QUALITY SAMPLING STATIONS
● SEWAGE TREATMENT PLANT

Figure D-2

SEWER OUTFALLS IN CALUMET AREA

Table D-5

MAJOR COMBINED SEWER OUTFALLS TO IHC
Source: Combinatorics (1974)

Municipality	River Mile Location	Combined Sewer Description	Peak Flow [cfs]		Average Flow [cfs]	
			1 yr. storm	5 yr. storm	1 yr. storm	5 yr. storm
Gary	8.34, 8.26	Outfalls .006 and .007	215.6	327.4	116.1	173.0
Gary	7.10, 7.04	Outfalls .008 and .009	593.4	892.4	305.8	455.2
Gary	6.00, 5.77	Outfalls .010 and .011	310.7	466.7	159.4	176.7
Gary	3.46	Outfall .012	189.6	286.5	99.7	148.3
Hammond	1.90 (West Branch)	Treatment plant bypass	70.0	100.0	35.0	50.0
East Chicago	2.4	Cline Ave. Outfall Alder St. pumping station (storm water and combined	301.4	455.2	158.2	235.5
East Chicago	.7 (West Branch)	Treatment plant bypass	128.0	192.7	66.2	98.6

not yet receiving any diverted flow and the possible need for a re-bid by the contractor may delay completion until the end of 1974. The two combined sewer overflow points to the GCR are located 400 yd and 1000 yd, respectively, west of the Cline Avenue bridge. These wet weather discharges will be diverted to the detention lagoon at the WTP as soon as the new interceptor sewer and the pumping station expansion projects are completed.

No interim chlorination is being provided, since the District has been too uncertain about the time delay to justify it economically (Sweeney 1973). There are no data available to judge the effects of these sources on water quality.

The storm water discharge from the Canal St. pumping station to the IHC is a result of sewer separation of the area bounded by the IHC on the east and Indianapolis Blvd. on the west. The Canal St. pumping station has discharged unchlorinated storm water to the IHC beginning about October 1971.

On the east side of the IHC, opposite of the Canal Street pumping station discharge point, is the Michigan Avenue pumping station combined sewer overflow discharge point. This discharge is tentatively being considered for treatment by microstraining and chlorination as opposed to the alternatives of sewer separation, expansion of sewer capacity or detention basin methods of controlling this problem.

2. THE HAMMOND SANITARY DISTRICT

The Hammond Sanitary District (HSD) was formed in 1938 and includes the corporate boundaries of the cities of Hammond and Munster. The HSD also services the cities of Whiting, Griffith and Highland by contracted agreement. The total population served by the District is about 175,000. There are also several industries discharging to the HSD, including American Maize and Lever Brothers.

2.1 The District Wastewater Treatment Plant

The following description of plant status is from HSD personnel (Sweeney 1973).

The HSD wastewater treatment plant is located on the west branch of the Grand Calumet River. See plant "A" on map, Figure 4.1. The plant was put in operation in 1942 and incorporates an activated sludge secondary treatment process with a 36-mgd capacity. The plant is often overloaded, since flows through the plant vary from 36-42 mgd. The plant is presently under construction to expand the secondary treatment capacity to 48 mgd by 1974 as recommended by the Four State Lake Michigan Enforcement Conference in 1968, and in a follow-up 180-day notice issued by the U.S. EPA, Enforcement Division on October 12, 1971. Although the ordered date of completion was December 7, 1973, delays in equipment delivery will cause completion to be delayed until March 1974.

The appearance of the receiving stream was very bad during IITRI sampling on November 30, 1973, with unsightly growths, anaerobic conditions, and floating sewage; however, chlorination of effluents is apparently effective, since the bacterial count is not high (Table 16.4 , Chapter 16).

The plant effluent discharged to the Grand Calumet River has deteriorated somewhat during the last year because of the construction. Preconstruction averages are found in Table D-2. Even these do not meet 1968 Lake Michigan Enforcement recommendations of 5 mg/ℓ BOD and suspended solids.

Shock loadings of organics from the American Maize and Lever Brothers' plants have tended to impair plant efficiency at times, as each plant discharges effluent of extremely high BOD and suspended solids to the sewers at inconsistent intervals (Sweeney 1973). This problem is mentioned in the U.S. EPA pretreatment guidelines (1973). The Swift Chemical plant which is now closed but which is soon to be operated by Ashland

Chemical Company, was responsible for the discharge of oil emulsions which broke down into oil globules when within the sewers and caused serious pump-screen clogging, impairment of plant processes, and additional disposal problems. Pretreatment should be required, with effective enforcement of pretreatment regulations.

Because the direction of the flow in the Grand Calumet River at the point where the District WTP discharges is variable, a barrier dam to be placed immediately to the east of the plant in the Grand Calumet River was proposed by several agencies to serve as a control structure (Combinatorics 1974). The barrier dam is still being considered by the HSD since this method of preventing the high phosphorus levels in the plant discharge from reaching Lake Michigan might be less costly than the installation and operation of permanent in-plant phosphorus reduction facilities. The dam is being considered by Indiana SPCB, although diversion of sewage effluents to Illinois waters might not be approved.

The cities served by the HSD have predominantly combined sewer systems, and force mains are necessary to maintain flow because of the level topography. The sewage from the city of Hammond accounts for about 75% of the total flow to the plant, with about 0.5 mgd being contributed from both American Maize and Lever Brothers. Whiting, with domestic sewage from a population of 7,000, contributes 2.5 mgd average flow. The municipalities of Griffith and Highland contribute average flows of about 2 mgd and 3 mgd, respectively.

The City of Whiting has recently held discussions with the U.S. EPA and Indiana SPCB concerning the construction of its own wastewater treatment plant; but with the trend in wastewater treatment toward regionalization, Whiting was urged to continue its contract with the HSD. Whiting is presently doing sewer improvement work to try to decrease a problem of infiltration of water into its sewers.

2.2 Planned Plant Improvements

As previously stated, the HSD treatment plant capacity will be expanded to 48 mgd by the spring of 1974 according to HSD personnel (Sweeney 1973). This expansion will also increase digester capacity and provide nitrification tanks. Phosphorus removal facilities are not planned because of uncertainty about building a dam. The 80% P removal requirement is not being met. Plans for AWT for the HSD plant were submitted to the state for approval on October 15, 1973, and call for a system of multimedia filters (gravity sand filtration) which are expected to meet the 1968 Lake Michigan Enforcement Conference requirement of BOD and suspended solids effluent levels of less than 5 mg/ℓ. This is to be completed by February 15, 1975 according to agreement with U.S. EPA. The HSD is scheduled to obtain 1974 funding for AWT.

2.3 Combined Sewer Overflows

The HSD has subdivided its District into 17 distinguishable drainage basins, and it does a commendable job of reporting the discharges. The combined sewer overflow discharge points from these areas and monthly volumes discharged are listed in Table D-6. The locations are also shown in Figure D-2.

HSD has been pursuing a program of constructing relief sewers over the last ten years to intercept combined sewer overflows. These were designed and located so as to provide the trunk phase for eventual sewer operation. In completing this separation, the District is planning construction of lateral sewer connections to relief trunk sewers and the elimination of surface drainage inlets. The District expects the remaining planning and construction for separation and chlorination of storm discharges to cost nearly $30 million in the next five years.

Table D-6

COMBINED SEWER OVERFLOW - HAMMOND SANITARY DISTRICT*
Million gallons per month

Overflow Discharge Location	1972					1973							
	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
GRAND CALUMET RIVER													
Sohl Ave.	26.9	43.7	5.4	5.7	16.1	7.0	0	7.1	7.7	28.9	12.1	9.4	7.7
Johnson Ave.	25.2	9.2	2.5	4.6	9.4	3.8	0.2	5.6	6.5	16.5	5.6	51.5	.2
Kennedy Ave.	32.9	40.0	14.2	32.1	34.0	14.5	1.0	37.9	40.2	28.6	18.1	11.3	7.1
Kennedy Ave. (New Bldg.)	30.9	38.3	25.1	39.9	41.3	38.3	19.2	46.4	48.8	43.7	32.3	10.8	9.1
Columbia Ave.	188.1	224.5	193.4	355.3	283.9	323.2	209.0	389.1	530.3	430.4	313.0	37.6	36.9
Sub-Totals (MG)	304.0	355.7	240.6	437.6	384.7	386.8	229.4	486.1	633.5	548.1	381.1	120.6	60.9
LITTLE CALUMET RIVER													
Walnut Ave.	2.0	1.3	6.7	17.9	19.8	9.6	0.2	21.1	40.1	12.1	8.5	2.2	.4
Kennedy Ave. Ejector	1.1	14.0	1.3	10.0	12.6	1.8	0.0	4.5	5.3	9.8	3.6	1.3	.2
Baring Ave.	0.4	7.1	5.5	38.4	43.8	16.8	10.6	35.2	32.5	4.6	8.6	6.5	3.4
Tapper Ave.	13.2	14.6	5.9	21.2	19.2	7.9	0.1	21.4	22.6	6.8	12.5	4.0	1.0
173d - Homan Ave.	18.9	5.6	2.5	9.8	10.6	1.8	0.02	13.4	1.8	9.6	5.1	1.0	.1
Hohman - Munster	1.1	1.1	0.6	2.1	1.5	9.1	0.01	2.1	3.7	1.3	0.8	0.3	.1
Van Buren Ave.	1.6	2.0	0.7	2.8	3.8	5.1	2.0	4.5	0.3	2.1	1.1	0.2	.6
Jackson Ave.	9.0	39.2	3.5	17.2	44.8	51.1	0.0	13.1	2.5	1.2	0.7	0.0	0.0
Indianapolis Blvd.	1.7	4.3	4.4	8.1	19.2	24.0	0.0	17.8	33.5	25.1	6.8	3.5	1.6
Sub-Totals (MG)	48.9	89.2	31.1	127.5	175.3	127.2	12.9	133.1	142.3	72.6	47.7	19.0	7.4
WOLF LAKE (Storm water only)													
Roby	10.0	10.9	10.2	2.7	11.1	12.3	8.0	12.3	0.5	12.5	11.4	.2	5.1
Forsythe Park	5.7	56.7	4.3	19.9	28.8	45.1	17.4	10.4	38.9	47.0	45.3	.2	4.9
Sheffield Ave.	3.1	3.7	0.9	4.5	1.9	3.3	1.5	2.6	2.8	4.8	2.5	.1	.8
Sub-Totals (MG)	18.8	71.3	15.4	27.1	41.8	60.7	26.9	25.3	42.2	64.3	59.2	.5	10.8
LAKE MICHIGAN													
Robertsdale	40.9	40.3	41.1	60.0	33.5	30.3	12.3	52.4	92.4	85.0	60.3	31.5	12.3
(Chlorinated storm water as of May, 1973).													
GRAND TOTALS (MG)	412.6	556.5	328.2	652.2	635.3	587.0	281.5	696.9	910.4	770.0	548.3	171.6	91.4

*Source: HSD Monthly Combined Sewer Overflow Reports.

Already completed in this large-scale plan is the complete separation of the combined sewer overflow in the Robertsdale area. The Robertsdale pumping station overflow discharge to Lake Michigan (Atchison Avenue extended) was the subject of federal enforcement action in the form of a 180-day notice by the Enforcement Division of U.S. EPA issued on October 12, 1971. As of May 1973 the Robertsdale discharge to Lake Michigan consists only of chlorinated storm water, according to HSD personnel (Sweeney 1973). This individual action by the HSD has cost about $4 million in its entirety.

The contract areas of the District have also been subject to enforcement action in regard to combined sewer overflow discharges. The City of Whiting was issued a consent decree by the District Court on September 6, 1973, which ordered its two combined sewer discharges to Lake Michigan to be diverted by November 15, 1974. Whiting is planning a 30 million gallon detention basin to meet this requirement at an estimated cost of $3 million. A construction grant was approved by U.S. EPA in 1973.

The Indiana SPCB ordered the town of Griffith to cease from discharging of combined sewer overflow by December 31, 1976. See Figure D-2. Griffith is therefore proposing to build a 34-mgd WTP to treat its combined sewer overflow.

Highland has submitted plans to the Indiana SPCB and is awaiting funding to complete its sewer separation in the northeast part of town. This would eliminate combined sewage overflow from its two overflow discharges.

3. THE GARY SANITARY DISTRICT

The Gary Sanitary District (GSD) serves over 200,000 people and various industries in Gary, East Gary, and Merrillville. The GSD was formed in 1938, and the District plant was put in operation in 1940. It is located on a 52-acre site on the east branch of the Grand Calumet River. (See Figure D-1.) Improvements in facilities have been made, mostly through a $6 million expenditure for expansion in 1962.

The Merrillville Conservancy District negotiated a contractual agreement with the GSD to treat its sewer flows subsequent to 1969. As of the end of 1972, the flow from Merrillville to the Gary District plant was averaging 2 mgd.

The Miller Treatment Plant in East Gary was shut down in July of 1971, and all East Gary sewage is now diverted to the District plant (a flow averaging about 1.5 mgd). Gary has predominantly a combined sewer system, while East Gary and Merrillville have separate sewer systems.

3.1 The District Plant

The GSD WTP has a primary design capacity of 80 mgd and activated sludge type secondary treatment capacity of 60 mgd. Chlorination is now provided for disinfection of the effluent discharged to the Grand Calumet River, which flows into the Indiana Harbor Canal and hence, Lake Michigan. The yearly average flow in 1972 was 46.5 mgd, and the 1972 average effluent BOD and suspended solids levels were 29 mg/ℓ and 51 mg/ℓ, respectively. The 1973 monthly averages of some effluent parameters are listed in Table D-7. The flow has increased, with no improvement in BOD or solids removal.

3.2 Planned Treatment Plant Improvements

As a result of a court decree initiated by Indiana SPCB, and a U.S. EPA 180-day notice, the GSD is being forced to improve its District plant effluent through implementation of phosphorus removal facilities and AWT facilities. Combined sewer overflows have also been the subject of these actions, and plans for their chlorination and eventual elimination are to be drawn up. The original suit and notice required these actions to be completed by December 31, 1972. This deadline was not met. The goals were as follows:

Table D-7

GARY SANITARY DISTRICT TREATMENT PLANT*
PERFORMANCE DATA 1973

	AVG. FLOW MGD	BOD(p.p.m.)		SS(p.p.m.)		AMMONIA (p.p.m.)		PO_4(p.p.m.)		OVERALL PERCENT PURIFICATION	
		RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL	BOD	SS
JANUARY	55.9	128	28	219	55	6.4	5.2	6.9	4.3	78	75
FEBRUARY	49.6	125	31	220	82	9	8	7	5	75	63
MARCH	55.0	126	42	294	74	-	-	-	-	67	75
APRIL	61.6	102	32	207	70	8	4	11	5	68	66
MAY	57.7	93	15	187	25	9	5	16	11	84	86
JUNE	58.0	104	22	214	45	10	5	20	13	79	79
JULY	50.43	151	26	266	38	8	3	22	13	83	86
AUGUST	51.0	238	29	449	40	13	10	22	13	88	91

*Source: Gary S.D. WTP Monthly Operating Reports.

- Phase A consists of phosphorus removal to a concentration 1 mg/ℓ as P or 80% over-all removal, and improvements to preliminary and primary parts of the treatment system.
- Phases B and C consist of Secondary Treatment improvement, sludge handling improvements, and construction of AWT to attain the 5 mg/ℓ BOD and suspended solids ordered, and to provide a high degree of nitrification.
- Permanent phosphorus reduction facilities are to be capable of 80% removal.
- Interim chlorination of storm and combined sewer overflows, and in-plant regulator control facilities is planned.

On January 24, 1973, the GSD received a federal grant of $3,996,150 for Phase A construction, but because of an injunction brought by a citizen against the bond sales by the GSD, construction was delayed.

3.3 Storm and Combined Sewer Overflows

The GSD is responsible for seven combined sewer overflow discharges and a separate storm sewer system discharge to the Grand Calumet River. The seven combined sewer overflows are located at Rhone, Island Street, Alley 9E, Polk Street, Pierce Street, Bridge Street, Chase Street, and Colfax Street. See Figure D-2 for locations. Disinfection or control of these discharges is being implemented by the end of 1973. Phase A improvements are to provide for the control of the operation of the combined sewage regulators on sewer interceptors at the wastewater treatment plant, and for some improvements in pumping station and interceptor flow capacity.

4. CHESTERTON

The Chesterton, Indiana, wastewater treatment plant serves the town of Chesterton and the town of Porter, which have a combined population of about 10,000. The plant uses an activated sludge type secondary process and has a 1.5 mgd capacity. The effluent is discharged to Beaver Dam Ditch, which flows into the Little Calumet River and thence to Burns Ditch and Lake Michigan. The 1973 effluent parameter levels are listed in Table D-8.

The Indiana SPCB held a hearing on January 6, 1972, to determine the need for Chesterton WTP to install phosphorus reduction facilities capable of 80% P removal. An order was issued which called for December 31, 1972, completion of such facilities. Chesterton contested this order, but has since agreed to install the required facilities. These facilities plan to use pickling acid for P removal rather than the customary ferric chloride. The facilities were expected to be operational by the end of October 1973.

Chesterton has also submitted plans for approval to the state for storm water separation of the present combined sewer system.

5. PORTAGE WTP

The Portage WTP serves its 20,000 plus population through a separated sewer system and its 3.0-mgd activated sludge type secondary treatment facilities. Phosphorus removal facilities have been operational since February 1973, and the chlorinated effluent is discharged to Burns Ditch. Monthly effluent levels for 1973 are reported in Table D-9.

6. HOBART WTP

The Hobart WTP serves a population of about 21,000, by a combination of combined and separated sewers. The 2.1-mgd design capacity at the WTP is often overloaded due to sewer infiltration problems. Performance data are given in Table D-10. The

Table D-8

CHESTERTON WASTEWATER TREATMENT PLANT REPORTS*
1973

	Daily Avg. Flow (MGD)	BOD (mg/l)		Susp. Solids (mg/l)		Percent Purif.	
		Raw	Final	Raw	Final	BOD	SS
Jan.	1.2	87.8	5.8	69	6	93	91
Feb.	1.3	77	7	79	9	90	89
Mar.	1.2	87	9	69	6	90	91
Apr.	1.3	79	4	83	6	94	92
May	1.2	106	7.4	73	6	93	92
Jun.	1.5	142	7.6	51	6	94	88
Jul.	1.2	101	5	71	6	95	91
Aug.	.92	97	4.4	98	5.5	94	95
Sep.	.83	99	10.3	118	4	89	96

*Source: Chesterton WTP Monthly Operating Reports

Table D-9

TOWN OF PORTAGE WASTEWATER TREATMENT PLANT REPORT*
1973

	Daily Avg. Flow (MGD)	BOD (mg/l)		Susp. Solids (mg/l)		Percent Purification		Phosphorus		
		Raw	Final	Raw	Final	BOD	SS	Raw	Final	Percent
Jan.	1.14	159	7.7	47	6.9	98.1	95.8	8.3	4.0	51.1
Feb.	.734	214	7.0	109	7.6	96.7	93.0	6.0	1.65	72.7
Mar.	1.16	192	9.8	111	7.5	94.8	95.2	5.6	1.3	76.7
Apr.	1.49	185	24.3	72	18	86.8	75.0	4.16	1.1	65.8
May	1.30	186	11.5	102	6.4	93.8	93.7	3.0	.5	83.9
Jun.	1.39	178	5.9	157	6.3	96.6	95.4	3.7	1.0	69.5
Jul.	1.06	319	7.4	180	5.5	97.6	96.9	4.36	.67	84.9
Aug.	1.04	321	7.0	175	6.0	97.8	96.5	6.9	.3	79.3
Sep.	1.10	333	7.3	178	9.7	93.0	94.5	-	-	-

*Source: Portage WTP Monthly Operating Reports.

Table D-10

HOBART WASTEWATER TREATMENT PLANT
1973 OPERATING REPORTS*

Month	Avg. Flow MGD	BOD		Suspended Solids		% Removal	
		Raw	Final	Raw	Final	BOD	SS
Jan	2.98	66	4.3	56	4.4	93.5	90.4
Feb	2.76	75	4.2	62	4.6	94.4	91.0
Mar	2.75	70	4.2	68	4.7	94.0	93.1
Apr	2.93	77	4.6	61	4.4	94.0	93.0
May	2.73	107	3.1	60	4.4	94.0	94.5
Jun	2.99	100	5.9	83	4.4	94.0	93.0
Jul	2.45	140	6.1	99	4.9	95.6	95.0
Aug	2.23	125	9.4	102	6.8	94.4	98.5
Sep	2.11	168	11.5	122	11.3	92.6	90.7
Oct	1.99	161	13.5	116	10.0	91.6	91.0
Nov	2.01	145	10.0	106	7.7	93.0	92.7

* Hobart WTP Monthly Operating Reports

chlorinated effluent is discharged to Deep River. Plans for expansion to a 5-6 mgd design capacity and for AWT implementation are awaiting federal funding. Hobart expects this to be done by the end of 1975.

The Hobart WTP is presently experimenting with adding increased polymer concentrations to upgrade the existing plant efficiency. There is a serious problem with the method of using pickling liquor (acid) for phosphorus removal. The liquor crystallizes within the piping system and has caused blockage of piping. The facilities have thus been inoperable since September 1973.

7. CROWN POINT WTP

Crown Point has a population of about 13,000, and the town is served by a combined sewer system. The WTP has an existing design capacity of 1.8 mgd, but is awaiting federal funds for planned expansion to a 5-mgd design capacity and implementation of AWT in the form of polishing lagoons.

The WTP has been achieving the required 80% phosphorus reduction, as these facilities have been operable since January of 1973. Effluent is chlorinated and the discharge is to Beaver Dam Creek, a tributary of Deep River. Performance data are given in Table D-11.

The combined sewers are routed to the WTP, but in times of extremely wet weather the increased flow rates often cause overflow to Beaver Dam Creek of untreated combined sewer waste water. Sewer separation is presently underway, and storm waters will be routed away from the plant.

8. SALT CREEK BASIN

There are eight wastewater treatment plants in the Salt Creek Basin. The plants are listed in Table D-12. The largest of these is the city of Valparaiso's plant. The location of these plants is shown on Figure D-1.

Table D-11

TOWN OF CROWN POINT WASTEWATER TREATMENT PLANT REPORTS*
1973

	Daily Avg. Flow (MGD)	BOD (mg/l) Raw	BOD (mg/l) Final	Susp. Solids(mg/l) Raw	Susp. Solids(mg/l) Final	Percent Overall BOD	Percent Purif. SS
Jan.	1.47	78	14	56	10	82	82
Feb.	1.51	64	15	70	18	76	74
Mar.	1.74	53	14	46	16	73	82
Apr.	1.65	44	10	63	17	77	73
May	1.60	88	19	37	10	78	72
Jun.	1.67	55	11	85	10	80	88
Jul.	1.88	80	22	105	11	72	89
Aug.	1.92	88	18	109	11	78	83

*Source: Crown Point WTP Monthly Operating Reports.

Table D-12

SALT CREEK BASIN WASTEWATER TREATMENT PLANT REPORTS[1]

WTP	Design Cap. (MGD)	Avg. Flow (MGD)	Avg. Effluent Loadings (Jan-June 1973) BOD (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)
Valparaiso	6	3.1	20	20	0.5
South Haven Subd.	1.4	0.5*	61	20	0.1
Pleasant Valley Mobile Home Park	0.080	0.013*	2.2	-	-
Robbinswood Subd.	0.078	0.026	10	0.8	2.0
Oak Tree Park Mobile Home Park	0.063	0.017	38	2.5	23.0
Elmwood Mobile Home Park	0.048	0.04*	7.3	1.7	2.3
Sands Mobile Home Park	0.015	0.01*	14	1.2	5.0
Porter County Home	Septic Tank	0.003	77	14	-

*Estimated.

[1] From: Report of Survey - Salt Creek Watershed, Porter County, In., July 1973, Div. Water Pol. Control, IBOH.

8.1 Valparaiso WTP

The Valparaiso WTP serves in excess of 20,000 people with an activated sludge type secondary treatment process. Construction completed in May 1973, at a cost of $2.2 million, has provided for an expanded plant design capacity of 6 mgd. The plant is also providing treatment for phosphorus removal and chlorination of its effluent to Salt Creek. Performance data are given in Table D-13.

Advanced wastewater treatment facilities are being planned, and are expected to be operational by 1977.

The system of combined sewers in the Valparaiso plant's service area has serious infiltration problems, causing increasing flow rates to the plant.

8.2 South Haven Subdivision WTP

The South Haven Subdivision WTP has an existing 0.70 mgd capacity but construction is being completed to give the plant a 1.4 mgd activated sludge secondary capacity with advanced waste treatment and chlorination facilities. The plant will serve about 2400 lots in the South Haven and St. Michaels Subdivisions, about 165 mobile home units at Meadow View Mobile Home Park, and 560 camp sites at Camp Butternut Springs.

8.3 Sands and Elmwood Mobile Home Park WTP

The Sands and Elmwood Mobile Home Parks' treatment plants discharge into Damon Run which is tributary to Salt Creek. The Elmwood Park WTP is an extended aeration type treatment process with chlorination facilities. Capacity is 48,000 gpd. The Sands Mobile Home Park's WTP capacity is about 15,000 gpd and of a similar extended aeration type. Effluent chlorination is provided and a terminal lagoon is used.

8.4 Pleasant Valley Mobile Home Park

The Pleasant Valley Mobile Home Park has an 80,000 gpd

Table D-13

VALPARAISO WASTEWATER TREATMENT PLANT REPORT**
1973

	Daily Avg. Flow (MGD)	BOD (mg/l)		Susp. Solids (mg/l)		Percent Purif.	
		Raw	Final	Raw	Final	BOD	SS
Jan.	4.0*	98.8	7.8	173	10	92.2	94.3
Feb.	2.24	110.3	11.8	163	6	99.1	96.3
Mar.	2.64	75.9	9.0	102	9	88.3	91.0
Apr.	3.69	78.1	8.3	180	8	89.4	95.4
May	3.18	100.3	100.2	145	13	85.8	91.0
Jun.	3.35	76.9	16.5	125	11	82.2	92.0
Jul.	2.61	90.6	13.3	146	13	85.2	79.4
Aug.	2.59	85.2	8.8	124	7	89.7	94.4

*Estimate
**Source: Valparaiso WTP Monthly Operating Reports.

extended aeration WTP which discharges to the Squirrel Creek tributary of Salt Creek. This plant also provides nutrient removal, chlorination and a terminal lagoon.

8.5 Neighborhood Utilities, Inc. WTP

Neighborhood Utilities, Inc., has a 78,000-gpd extended aeration WTP on the southeast side of Portage. It now has phosphorus removal facilities installed for its discharge to Salt Creek.

8.6 Oak Tree Mobile Home Park WTP

The Oak Tree Mobile Home Park is in the northern part of Porter County and has a 63,000 gpd extended aeration WTP. The plant effluent is chlorinated, and a terminal lagoon is provided with final discharge to Salt Creek.

8.7 Porter County Home Septic Disposal

The Porter County Home is served by a septic tank disposal system which discharges to Salt Creek. The discharge averages about 3000 gpd. It is the farthest upstream discharge known in Salt Creek.

8.8 Other Minor WTP and Proposed Systems

Several other minor systems exist. These include the Liberty School WTP, 0.05 mgd design capacity and Liberty Farms Mobile Home Park WTP, 0.036 mgd design capacity. Plans for a Lake Louise Subdivision WTP and Timber Lake Subdivision WTP with respective 0.092 mgd and 0.150 mgd design capacities have received preliminary approval from the Indiana Board of Health. The planned Burns Harbor Estates WTP, 0.064 mgd, and a housing complex at R. 36, R6W, Section 16; 0.045 mgd WTP's have not yet been approved.

9. THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

The MSD has no sewage treatment plant facilities whose discharge is tributary to Lake Michigan. There is a combined sewer overflow which diverts heavy run-off flows from the 95th St. pumping station to the Calumet River via the Howard slip. As reported by the MSD, diversion occurred a total of 4 hr and 32 min in 1972. This discharge is chlorinated. During discharge its flow in the Calumet River is assumed to be towards the Lake, since flow to the Illinois waterway through the O'Brian Lock is limited. The Chicago Water Department's Surveillance Crew has reported that during 51 weekly Calumet Industrial Area Surveys in 1970 the Calumet River flowed toward the Lake on 31 or 61% of the observations at the nearby 92nd St. bridge.

10. CONCLUSIONS AND RECOMMENDATIONS

Both the treated municipal effluents and the combined sewer overflows which discharge to the south Lake Michigan basin, have a definite, detrimental effect on the quality of these waters.

Lake Michigan is directly affected by the two combined sewer overflows at Whiting, by the extreme pollutional loadings from the IHC, and to a lesser extent by the pollutional loadings from Burns Ditch.

The water quality of the Grand Calumet River is quite degraded as a result of the high BOD, suspended solids, ammonia-nitrogen, phosphorus, and bacterial effluents from the Hammond, East Chicago, and Gary Sanitary District wastewater treatment plants. To correct the immediate problems, pretreatment of the industrial discharges to these plants should be required, including back-up facilities to prevent peak loadings that can upset the municipal treatment plants, monitoring of sources, and penalties for excessive peak loads from industries. If the industries presently discharging to municipal sewers wish to discharge to the Lake instead, then highly effective treatment should be required of them.

The planned advanced wastewater treatment facilities and expansion project should be expedited to help upgrade the quality of effluents flowing to the Lake via IHC. More rapid funding is

needed for this to be achieved. Hammond SD should proceed with a phosphorus removal process, since diversion of their effluent to Illinois waters is unlikely to be approved.

The high NH_3-N and bacteria concentrations in East Chicago treatment plant effluents cannot be remedied by the existing plant without control of ammonia and other materials coming from steel mills. The high level of NH_3-N in the plant effluents prevents effective chlorination with any reasonable chlorine dosage. High bacterial loadings in the IHC will continue until this problem is solved. High bacterial counts are an indication that other pathogens may be present, and constitute a threat to public health.

The planned implementation of AWT and the present work towards achieving 80% phosphorus removal in treatment plant waste water discharges should provide for a general improvement in water quality of the receiving waters. Further effort is needed (mainly by completing construction programs and monitoring performance) to achieve phosphorus effluent requirements of 1 mg/ℓ. See Chapter 17 for effect of the phosphorus reductions on the Lake. The control or elimination of combined sewer overflows is also needed to provide a very definite improvement in water quality. Monitoring should be continuous throughout this period of implementation of such improvements so as to document their value and serve as an example to other areas.

The Hammond SD should be commended for its monitoring of its combined sewer overflows. Other districts should be urged to follow similar practices.

The Gary SD should be forced to initiate a program to eliminate its combined sewer overflows to the Grand Calumet River, and to provide interim chlorination and monitoring. The combined sewer overflow elimination project in Whiting is being slowed by litigation opposed to the planned detention lagoon. This issue should be settled promptly and the project completed at the earliest possible time, since pollution from Whiting overflows is evident in the Whiting area. (See Chapter 16 in Vol. I of this report).

The water quality of the Little Calumet River is degraded because of the uncontrolled combined sewer overflows from the Hammond Sanitary District and the Highland and Griffith contract areas. Further planning and funding should be expedited to allow this situation to be remedied more quickly than it is presently scheduled to be done.

Deep River and its primary tributary Turkey Creek flow to the Little Calumet River and contribute above average phosphorus, BOD and suspended solids and coliform to Burns Ditch. In wet weather, high coliform counts and increases in BOD and suspended solids levels result from treatment plant by-pass. Those municipalities contributing flows should be required to do sewer infiltration studies and to correct the problem.

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